

RHEOLOGY AND RHEOLOGICAL TESTING OF
WESTERN CANADIAN BITUMINOUS COALS - Part II

FINAL REPORT

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SUMMARY

The rheology of three Western Canadian and two U.S. Appalachian coals were monitored over a three-month period to measure any effects of "aging" in the samples. The rheological properties were determined using a Ruhr Dilatometer operated under standard (DIN) and non-standard conditions. The coals were characterized through proximate and ultimate analyses. Petrographic characteristics of maceral distributions, vitinite reflectance, and microlithotypes were also performed. It was found that Western Canadian coals "aged" more than Appalachian coals over this time period.

In further work, one Western Canadian coal and one Appalachian coal of near identical mean maximum vitrinite reflectance were singled out for detailed study. Sample suites from each were obtained by sieving into three size fractions and then by sequential gravity separation of each fraction in cesium chloride solutions. Each fraction thus obtained was characterized by chemical, petrographic and rheological means. In this work, the rheological testing was extended to include Gieseler Plastometry run under standard (ASTM) and non-standard conditions.

In seven separate experiments, various percentages of fractions of one coal type (e.g. Western Canadian) were blended to match a given sample of the other type (e.g. Appalachian). A linear program was used to determine the blend compositions based on the analyses of the individual fractions obtained through the sieving/float-sink procedure. It was found that although Free Swelling Indexes of Western Canadian coals could be forced to approach those of Appalachian coals, no blend combination could force similarity in Ruhr or Gieseler measurements, performed under standard or non-standard conditions.

INTRODUCTION

Background

Western Canadian coals laid down in the Cretaceous era exhibit proximate analyses and heating values which fix their rank from high-volatile bituminous (Plains region) to low-volatile bituminous (Foothills and Rocky Mountain region). When tested in pilot ovens these coals produce coke of good stability either alone or in blends. They are, in fact, major component coals for Japanese and other Pacific rim cokemakers. Yet, many of these western Canadian coals, by interpretations of their apparent rheological properties, should not form coherent coke. The fact that they do contradict or at least leaves incomplete our understanding of the relationship of petrography, rheology, and resultant coke quality. The properties of the plastic phase in the coal-to-coke transformation, supposedly measured by standard rheological and instruments, critically affects the resultant coke structure and strength. It seems important, therefore, to understand why such rheological measurements appear to be such poor predictors of coke strength for the western Canadian coals.

Could it be that the test conditions used in the standard rheological procedures of dilatometry and plastometry are inappropriate to the Western Canadian coals? The conditions were developed, after all, primarily for European or Appalachian coals of the Carboniferous era. The Carboniferous coals of rank identical to the Western Canadian coals are known to have a different maceral composition (Berkowitz et al., 1974). Makeup of the inert macerals, in particular, differ between Appalachian and western Canadian coals of the same rank. Van Krevelen et al. (1959) has demonstrated that the nature of the inert maceral effects rheology so that it could be anticipated that procedures and test conditions for Carboniferous coals might not be suitable for coals of a different geological era.

The research program on coal rheology at the University of Waterloo, initiated in 1982, had as its ultimate objective an understanding of coal

rheology, specifically we aim at the development of a rheological procedure which will properly assess the coke quality achievable with Western Canadian coals. Immediate objectives were to compare the rheological properties measured under various test conditions vis-a-vis standard procedures, to identify the source of differences, and to devise test conditions (or even new instrument designs) which properly relate test rheology with the coking performance of the western Canadian coals.

Our first study, financed by an EMR Research Grant to our team (Professor P. Readyhough) demonstrated that the rheological test behaviour of W.C. bituminous coals could be dramatically improved by increasing the particle top size of the test sample and/or by raising the heating rate by at least 50% ($3^{\circ}\text{C}/\text{min}$ -- $4.5^{\circ}\text{C}/\text{min}$). A hypothesis was developed in that study which related the western Canadian and Appalachian coal differences in dilatation to the predominance in the western Canadian coals of inter-particle fusion rather than an intra particle process for trapping gas (Ramachandran, 1984).

The first contract in this series expanded Ramachandran's study by examining additional western Canadian coals and added to the earlier work a careful petrographic characterization of the coal samples used. It introduced further Appalachian coal samples, and examined the influence of ash removal and vitrinite concentration on the rheological test behaviour. That study (Waterloo Centre for Process Development, 1983) found a much stronger influence of cleaning on test behaviour for the western Canadian coals than for the Appalachian coals. For the former, a minimum vitrinite level of approx. 55% for positive dilatation was observed: as was a greater sensitivity to vitrinite content for these coals when compared to the Carboniferous Appalachian samples. The dramatic effect of top size and heating rate observed earlier were confirmed and we found that the relative effects of size and heating rate were larger for the western Canadian coals than for Appalachian coals.

Large differences in dilatation between Western Canadian and Appalachian coals were still observed even under changed operating conditions. These differences were attributed to the maceral compositions

and assemblies (microlithotypes) of these coals from vastly separated localities and unlike geological age. A significant difference between the coals was seen in the semi-fusinite content of the inertinite. This led us to conclude that a second swelling mechanism might be dominant in coals in which inertinite was distributed in a highly segregated and non-uniform manner in the coal mineral. This mechanism was thought to be through gas entrapment via bridging between adjacent coal grains as the plastic phase emerges. Such a second mechanism, one not wholly absent in Carboniferous coals, would explain the particle size and heating rate observations.

The second contract in this series, covered by this report, extended our study of test conditions to an additional rheological device, a Gieseler Plastometer, an instrument widely used in North America to measure rheological properties. It examined, furthermore, other possible sources of rheological differences beside the inertite differences, namely, different aging of the stored coals, initial textural differences, and finally the possibility that reactive macerals such as vitrinite swell differently in the Carboniferous and Cretaceous coals.

Objectives of This Study

Specific objectives were to:

- (a) extend the number of coal sources tested,
- (b) perform detailed rheological measurements on two very closely matched (R_o , maceral composition, ash) western Canadian and Appalachian coals,
- (c) extend the research to examine plastometry,
- (d) evaluate the effect of sample age on the rheological behaviour,
- (e) add textural evaluation of coal through BET-measurements,

- (f) further explore the influence of ash removal and vitrinite concentration on test rheology using, however, a different separation medium.

The tasks associated with these objectives were split into two parts. Part I deals with (d) above and was directed at identifying the coals to be used in the remainder of the work.

The primary objective of Part II was to compare rheological characteristics of two western Canadian and two Appalachian coals of nearly identical maceral compositions, ash content and particle size distribution. Since the possibility of finding such coals with such a close match of properties seemed remote, this objective was to be achieved by grinding and blending.

An extension was authorized in the last month of the work to add further tests of blends. Specific objectives were to see if blends of coals of the same geological era yield the same rheological values as a single coal of matched maceral composition, ash level and particle size and to test blends of mixed geological era to see if "additive" relations exist.

Textural evaluation was also included in Part II, whereas plastometry was performed in both parts.

WORK STATEMENT

Part 1

1. Three freshly mined western Canadian and three freshly mined US coals of similar rank (e.g. 1.15-1.25) having reasonably good rheological properties for FSI, Gieseler fluidity and Ruhr dilatation will be solicited. Care will be taken to assure that samples have measurable thermal rheological properties and that the US coals have almost identical rank as the Canadian coals. After receipt, all samples will be stored under refrigeration and under vacuum. Large enough samples should be solicited to complete work in Parts 1 and 2.
2. Immediately upon receipt, FSI's and standard dilatation analyses will be done on representative samples obtained by riffing.
3. Proximate, ultimate, petrographic* analyses and screen analyses will be done on the coals. Coals will be screened through 3,6,12,20,60,100 and 250 mesh screens to obtain their size distribution.
4. The above thermal rheology measurements will be repeated weekly on two Canadian and one US coal for an additional 2 weeks, and then at monthly intervals for an additional two months.

Another size distribution will be made on typical rheological samples for all 6 coals, -35, -60, -100, -170, -250 mesh.

- 5(a) Non-standard Ruhr dilatations and FSI's will be done on 60 x 100 mesh for all western Canadian coals and one US coal.
- (b) Petrographic and proximate analyses will be made on the coals used in 5a.
- * Petrographic analysis, unless otherwise stated, will include vitrinite reflectance, maceral analysis, and microlithotype identification.

Part 2

1. One Western Canadian coal and one US coal will be selected for additional work. The two coals should be identified (SIC) in rank R_o , ash, and both have measurable dilatations and fluidities. The US coal however will presumably have greater thermal rheological properties than the Canadian coal. If no two US and Canadian coals are identical in rank a blend of the US coals or Canadian could be considered if the vitrinite reflectances are similar. Adequate samples of the coals chosen will be taken to complete the following tasks.
2. The two coals will be crushed to -8 mesh and representative splits made to complete the tasks below.
- 3(a) Samples of the -8 mesh materials generated in 2. will be split and pulverized so that 3 samples of -8 mesh, -35 mesh and -60 mesh samples will be obtained for each coal.
- (b) Complete size distribution, BET, and non-standard thermal rheological tests that were not run in Part 1 for the various size consists will be completed.
- 4(a) A second (and larger) representative portion of the -8 mesh coals will be pulverized in stages and screened to obtain -8 x 35, -35 x 60 and -60 mesh materials. Large portions of these size fractions will be retained for tasks 5 and 6.
- (b) Giseler, FSI, dilatation and BET will be done on -8 x 36, -35 x 60 and -60 mesh materials. Petrography will be performed on the -8 mesh material.
- (c) Dilatations and FSI's will be determined on the two -100 mesh materials.
- 5(a) Sequential float-sinks will be carried out on representative portions of the -8 x 35, -35 x 60, and -60 mesh samples of the western Canadian

mesh samples will be pulverized to -60 mesh. Samples with SGs greater than 1.6 will not be included.

- (d) The 20 samples generated in 5c will be analyzed by Gieseler, dilatation, FSI. A size determination will be done on the -35, and -60 mesh samples.
- 6. The float/sink products from the Canadian coals will be blended and/or pulverized in such a manner so as to match (as closely as possible) the maceral analysis, ash content, and size distribution of the -8 mesh, -35 mesh, -60 mesh US coal samples generated in 3 above. Gieseler fluidities, dilatation, FSI and BET will be done on the 3 samples generated.
- 7. The final report will include an appendix of all analytical results, a description of all non standard procedures used, and a comprehensive discussion on the effects of vitrinite reflectance, maceral analysis, ash analysis, particle size, and the interaction of these parameters on the thermal rheological properties of the western Canadian and US coals investigated.

Minor modifications were made to the Work Statement in the progress of the research. These are noted in the text. In all cases, permission of the Scientific Officer was obtained for these modifications.

COALS EXAMINED

Coals were solicited by the research group directly from the mine operators or developers with the advice and consent of the Scientific Officer. These coals are indicated in Table 1.

Table 1

Coals Tested

<u>Designation</u>	<u>Description</u>	<u>Comments</u>
<u>Western Canadian</u>		
WC4	m vb	
WC5	m vb	Used in Part II
WC6	h v "A" b	Age testing incomplete due to the late arrival of sample
<u>Appalachian</u>		
AC3	m vb	
AC4	m vb	Used in Part II

The work statement called for a third Appalachian coal to be used. Despite a strenuous effort on our part, a suitable sample was not made available to us in time for inclusion in the Part I ageing study. Because of the large number of tests which were run and tight scheduling

requirements, permission was obtained from the Scientific Officer to drop this coal. When this decision was made, two suitably matched western Canadian and Appalachian coals had been identified so that a third Appalachian coal was not needed for the matching experiments in Part II.

EXPERIMENTAL PROCEDURES

General

A uniform set of procedures was followed in both parts of the research program. These reflected, as did details of all standardized test procedures, ASTM guidelines or practices set out in the Laboratory Manual of Stelco's R & D Department when specific guidelines were not available.

Handling

Coals received from mining companies were logged into laboratory data books with date and source, and were given a code number. They were stored in their original shipping containers, namely sealed drums until used. These drums were carefully labelled and stored in a dry, cool environment.

Storage

Raw coal samples that were cleaned by crushing, sieving to [-4] mesh, and gravity separation were stored in evacuated dessicators. These dessicators were placed in an ice box maintained more or less at 0°C. Samples from the gravity separation procedures of Part II were stored in the same way. Indeed, all samples of crushed or ground material were stored as described unless they were used in tests to be run during the immediate working day. Sample containers were marked with coal name, description and date of preparation.

Samples

All test samples - for dilatometry, petrography, chemical analyses, etc. were made up by quartering techniques as prescribed by the ASTM



1. Sieve Analysis as received
2. Proximate Analysis
3. Ultimate Analysis
4. Petrographic
5. Surface Area by B.E.T.
- 6 For the effect of aging with time
 - Sieve Analysis of (-8)(-35)(-60), As received mesh samples, Week 1
 - Dilatometry, Week 2
 - Standard DIN conditions, Month 1
 - Regular Non-Standard conditions, Month 2
 - Special Non-Standard conditions, Month 3
 - Plastometry
 - Free Swelling Index

FIGURE 1 ANALYTICAL PROCEDURES PERFORMED IN PART I

Manual. As described elsewhere, it was general practice to duplicate each test. In some cases, tests (such as FSI) were triplicated. Often, however, results are reported in the next section as a single number. When this occurs, that number shall be understood to be an arithmetic average of the original and replicated measurement.

Part I Program

This sequence of experiments was used to determine if different aging behaviour of western Canadian and Appalachian coals contribute to the rheological difference observed. More generally still, the sequence was to establish if aging was a factor in our study. The design of these experiments made use of the well-known logarithmic behaviour in which the rate of aging (or weathering) is rapid initially and then decays with time. The test sequence chosen was thus weekly for two weeks, and then monthly from the first to third month. Since the entire research program was confined to a year the first three months were assumed to be adequate to characterize the phenomenon if ageing required consideration.

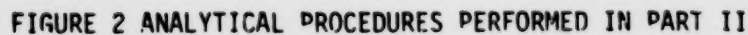
In the aging experiments, both standard and non-standard conditions were used. Dilatometry, plastometry and free swelling index were included to be able to assess aging effects on all tests and any interaction between aging and testing conditions.

Figure 1 shows the procedures used in this program. Of the procedures shown, sieve and proximate analysis followed rigorously the detailed procedures set out in the ASTM Manual. Test equipment built to the ASTM specifications were used in all cases.

Petrography was performed to closely follow procedures described in Stelco's Laboratory Manual. These procedures are essentially those adopted in coal laboratories throughout North America. Details of procedures and modifications introduced have been described in our previous report.

Table 2
Analytical Schedule

	A.						B.						C.						D.					
Coal	WC ₄	WC ₅	WC ₆	AC ₃	AC ₄		WC ₄	WC ₅	WC ₆	AC ₃	AC ₄		WC ₄	WC ₅	WC ₆	AC ₃	AC ₄		WC ₄	WC ₅	WC ₆	AC ₃	AC ₄	
Sieve Analyses	x	x	x	x	x				x		x				x		x			x		x		x
Proximate Analyses	x	x	x	x	x															x				x
Ultimate Analyses	x	x	x	x	x																			
BET	x	x	x	x	x				x		x				x		x			x				x
FSI	x	x	x	x	x				x		x				x		x			x				x
<u>Dilatometry</u>																								
Standard Conditions DIN	x	x	x	x	x																			
Non-Stand. Conditions	x	x	x	x	x																			
Special Non-Stand. Conditions	x	x	x	x	x																			
<u>Plastometry</u>																								
Standard Conditions DIN	x	x	x	x	x																			
Regular Non-Stand. Conditions	x	x	x	x	x				x		x				x		x			x				x
Special Non-Stand. Conditions	x	x	x	x	x				x		x				x		x			x				x
<u>Petrography</u>																								
Mean R ₉	x	x	x	x	x															x				x
Maceral Analyses	x	x	x	x	x										x		x			x				x
Micro lithotype Analyses	x	x	x	x	x										x		x			x				x



Other procedures used require more detailed description and are presented below.

Column A in Table 2 gives the procedures performed on each coal sample.

The program shown in Figure 1 was modified as follows. The apparent similarity of rank, ash, and reflectance of the WC 4 and the AC 3 coals led us to clean the latter coal. Consequently, the "on arrival" tests on this coal are not available. The late appearance of the WC6 coal caused us to miss the 1 week and 2 week measurements on this coal as the dates fell over the Christmas break when our laboratory was closed.

Part II Program

The primary objective of Part II - to see if western Canadian coals behave like Appalachian coals if the maceral composition are the same - was pursued by preparing different blend components through coal cleaning. Once these were available they could be mixed to match the maceral distribution characteristics of another cleaned, but not separated coal. To simplify the blending task, coals of matching rank, vitrinite reflectance and ash level were selected from amongst those examined in Part I. These coals, one of Cretaceous western Canadian coal and the other a Carboniferous Appalachian coal, were the blend sources. Procedures are summarized in figure 2. Each raw coal was crushed to [-8] mesh as the starting material. The samples were sieved to [-8], [-35], and [-60] mesh. A second portion was ground stagewise and sieved to [-8 x 35], [-35 x 60] and [-60] mesh. The former samples were used for analyses. The latter were subjected to sequential float-sink separation at specific gravities of 1.6, 1.45, 1.32 and 1.2.

In this year's contract we switched from an organic to an inorganic medium in order to avoid a possible influence of the halogenated hydrocarbon Certigrav on the coal samples. Comparison of the two different mediums, organic (Certigrav) and inorganic (cesium chloride), for the same coal showed only 1% higher yield of float for cesium chloride.

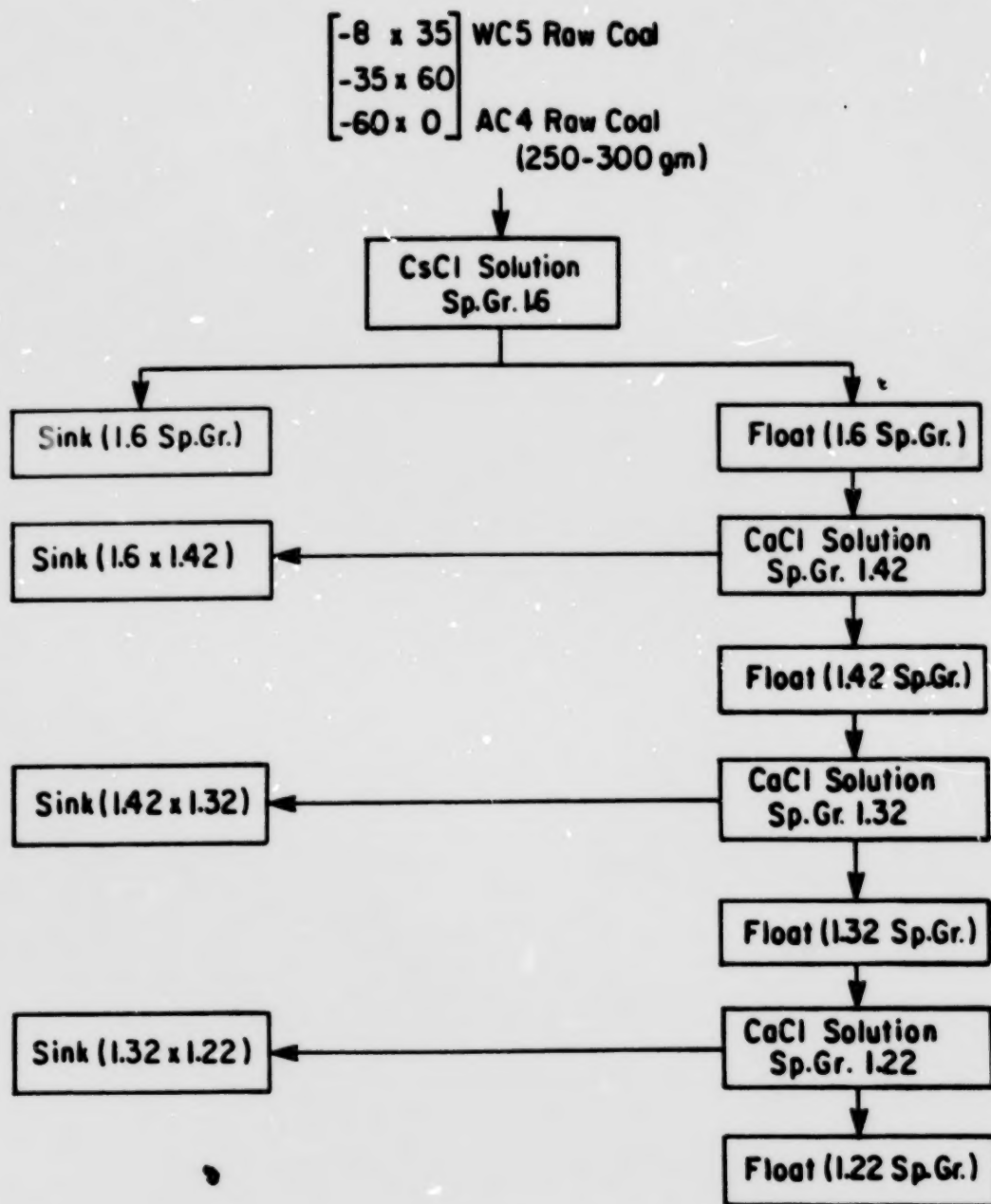


FIGURE 3 FLOAT-SINK SEPARATION PROCEDURE

The float-sink separation was performed according to the ASTM method, just slightly modified. 250-300 g of the ground coal samples ($[-8 \times 35]$, $[-35 \times 60]$ and $[-60 \times 0]$) were dispersed in 5L portion of cesium chloride solutions, mixed to achieve 1.6, 1.45, 1.3, 1.2 specific gravities. Care was taken to ensure complete dispersion of the feed coal in medium solution by constantly stirring the slurries. Stirring was then discontinued and the slurry was left overnight to permit complete separation of the sink and float. Float obtained from highest density was used as a sequential feed sample for the next lower specific gravity. The sink was retained for testing. Salt solution was stripped from these samples by at least three dispersions in and settling out of distilled water. Samples were air and vacuum dried and stored in dessicators as described earlier.

The procedure described above is summarized in Figure 3.

Analyses performed on the forementioned $[-8 \times 0]$, $[-35 \times 0]$, $[-60 \times 0]$, $[-100 \times 0]$ mesh samples include:

1. Size distribution of the $[-8 \times 0]$, $[-35 \times 0]$, $[-60 \times 0]$ samples by sieving with -8, -35, -60, -100, -170, -270 mesh sieves.
2. Apparent surface area by the BET method, at liquid N_2 temperature.
3. Free Swelling Index on the $[-100 \times 0]$ fraction.
4. Ruhr Dilatometry on the $[-100 \times 0]$ fraction at 3° and $4^\circ\text{C}/\text{min}$ heating rate.
5. Gieseler Plastometry on the $[-60 \times 0]$ fraction at 3° and $4^\circ\text{C}/\text{min}$ heating rate.

The tests are summarized again in Column B of Table 2. Column C of the table show the test performed on the samples subjected to separation. The test then done on the raw coal screen fraction of $[-8 \times 35]$, $[-35 \times 60]$, $[-60 \times 0]$ were:

1. Apparent surface area by the BET method at liquid N₂ temperature.
2. Size distribution of the fractions by sieving with -8, -35, -60, -100, -170, -270 sieves.
3. Ruhr dilatometry at standard DIN conditions on a [-60] sample prepared from each fraction.
4. Ruhr Dilatometry at 4.5°C/min on each fraction.
5. Giesler plastometry at 3° and 4°C/min on each fraction.
6. Free Swelling Index on the [-60x0] fraction.
7. Maceral analysis, mean reflectance and microlithotype analysis.

The same set of tests were carried out on the sink samples and on the final float at 1.22 sp. gr. of the [-8x35], [-35x60] and [-60x0] fractions. In addition, proximate analysis were performed and a [-60x100] sample was prepared for each fraction. Dilatometry was performed at 4.5°C/min for this sample. Column D in Table 2 lists these tests.

Dilatometry

All measurements were made on an instrument designed to meet DIN standards supplied by Standard Instrumentation of Wheeling, West Virginia. The instrument was furnished with an electronic temperature controller/programmer which closely controlled the rate of heating. At 3°C/min, the controller maintained the rate within 0.2°C/min. Although the dial indicated the instrument was capable of 10°C/min, testing showed that the maximum heating rate was only 4.5°C/min. The tester arm which followed the movement of the dilometer piston was coupled with a transducer which converted the piston movement to a voltage. Finally the device contained A/D converters and a printer which provided continuous printed record of temperature and piston position. These features made identification of the softening, maximum contraction, maximum dilatation temperatures

straightforward. However, the discrete nature of the sampling of position and temperature introduced a minor error in determination of c , d , and the temperature parameters. Ramachandran (1984) gives a complete description of the Waterloo Ruhr model dilatometer and discusses limitations of the unit as well as errors introduced by discrete sampling.

The dilatometer tube was thoroughly cleaned after each measurement. Once during the course of this year's work, it was rebored to ensure that its dimensions were correct.

Plastometry

Measurements of coal rheology during the coking process can be followed by applying a shear stress to the sample as well as by examining contraction and dilation. A Gieseler unit was used in this contract. This type of Plastometer is the most common of a number of instruments measuring plasticity, which is analogous to viscosity. This instrument measures the rotation of a specially designed rabble-armed stirrer in a compacted 5g coal charge while the coal is being heated at $3 \pm 0.1^\circ\text{C}/\text{min}$ and records the fluidity in dial divisions per minute (ddpm). The stirrer is attached to a constant torque motor adjusted to rotate at a constant rate of 280 rpm in the empty crucible. The disc attached to the stirrer of the original instrument is divided into one hundred dial divisions: the maximum speed of the stirrer is therefore 28,000 ddpm.

Coking coals, upon heating, become fluid and the stirrer begins to rotate. The coal fluidity increases to a maximum, then steadily declines until all fluidity is lost as the coal resolidifies into semicoke. Critical points are the softening temperature T_1 - the temperature at which the disc attached to the stirrer rotates at 1.0 dd/min; fusion temperature T_2 - the temperature at which the dial reading is 5 ddpm; maximum fluidity temperature T_3 - the temperature when the dial movement is at its maximum ddpm reading; final temperature T_4 - the temperature when the dial movement returns to 1.0 ddpm; resolidification temperature T_5 - the temperature when dial movement ceases. These temperatures may be seen in Figure 4 (Readyhough, 1983).

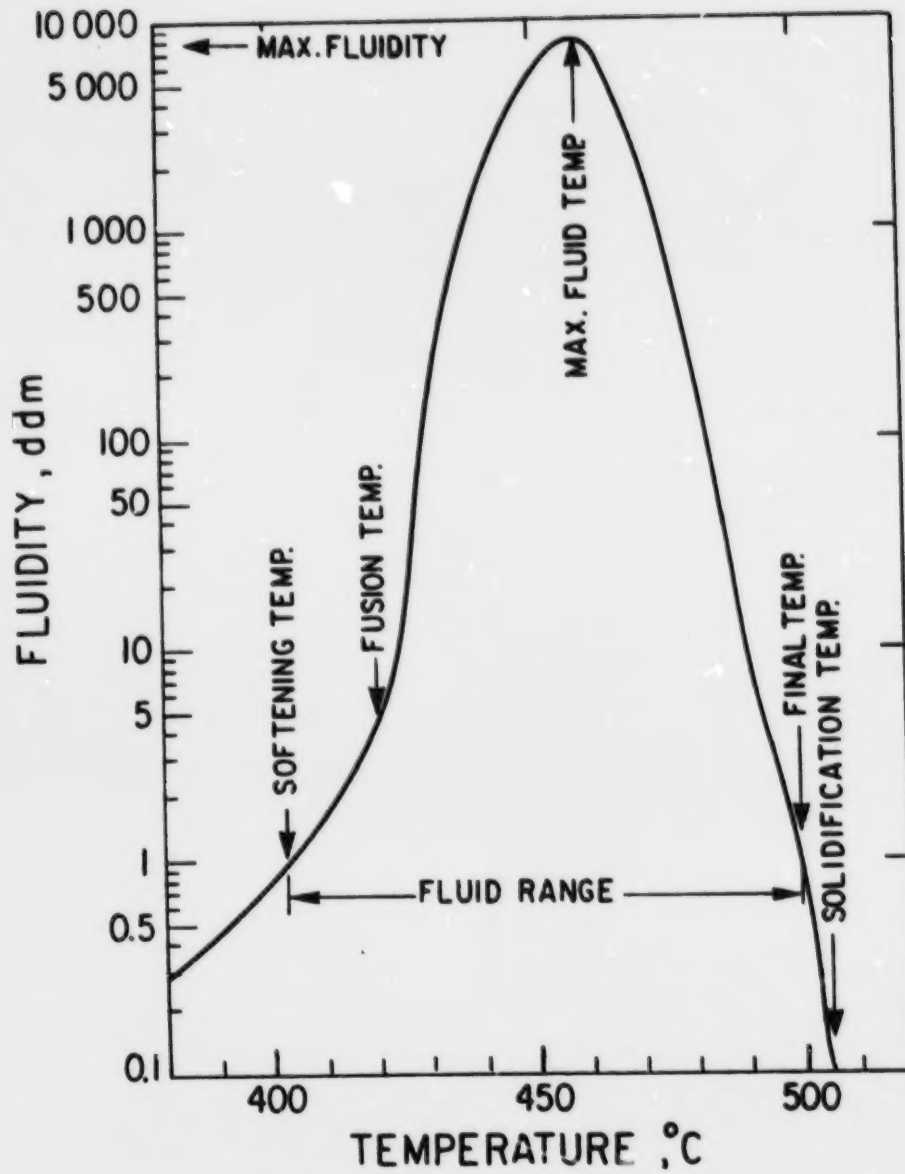


Figure 4 Typical Fluidity Behavior of a Coking Coal Showing How Temperatures are Defined

The fluid range of the coal is taken to be the temperature range between the softening and final temperature readings. The maximum fluidity varies with the rank of the coal. It is known that the softening and final temperatures increase with rank.

The Gieseler Plastometer used in this project was obtained under a rental agreement between the University of Waterloo and the supplier - Standard Instrumentation of Wheeling, West Virginia. A schematic of the instrument appears in Figure 5. This figure suggests the operating procedure. The solder pot is brought to temperature and held at temperature. The sample holder and stirrer are lowered in place to begin the measurement. The solder is heated at a set rate thereby raising the sample temperature. The rpm of the constant torque stirrer is periodically sampled.

Figure 6 shows a photograph of the equipment installed in our test fume hood. Solder pot temperature is controlled electronically by a temperature programmer - controller virtually identical to the one used on our dilatometer. Rotation of the stirrer is read electronically and both rpm and temperature signals are digitized and printed by a tape printer contained in the control unit.

The initial furnace temperature stabilized in the Waterloo instrument around 330°C. Thus, 330°C was chosen as the initial setpoint instead of ASTM standard 300°C as a time-saving measure. Few coals exhibit fluidity below 340°C, so this change should not interfere with our measurements.

Temperature rate of rise of 3°C/min and coal sample of [-35] mesh are the ASTM-standard condition. Shut-off temperature is arbitrary, but was set for 540°C based on our preliminary observations. A standard packing procedure is prescribed and simple to fill the crucible. A specified pressure of compaction is not given tamping was used. As non-standard conditions, a temperature rate of rise of 3°C/min for [-8] mesh, 4°C/min for [-8] mesh, and 4°C/min for [-35] mesh were used.

Figure 5 Schematic of the Gieseler Plastometer (Standard Instrument Version)



Fig. 6 Gieseler Plastometer: (Standard Instrument Version)
as set up in the Coal Research
Laboratory of the University of
Waterloo

Surface Area Measurements

An Aminco Sorbomet was used to determine the apparent surface area of the coal samples. This semi-automated instrument permits simultaneous measurements of four samples. Coal samples were degassed at room temperature for several hours before measurements were made. These were carried out using nitrogen in sample holders held at -196°C in nitrogen filled dewar flasks. Surface areas were determined from the adsorption isotherms by the BET procedure which assumes physical adsorption on the coal surface conforming to the Langmuir isotherm.

According to Anderson et al. (1965) adsorption of N_2 at 196°C provides a measure of the area contained in pores having diameters greater than about 5 Nm. Micropores less than 5 Nm are not completely accessible to N_2 molecules because for these pore sizes the diffusion process is very slow at -196°C .

Petrographic Analysis

Standard North American petrographic analysis technique, patterned after ASTM standards D-2798-77, were performed. A pellet of [-20 mesh] coal is produced with epoxy tinted black. Polished to a smooth surface, 1000 points are identified at 600x magnification under oil. The entities noted are:

- vitrinite
- exinite and resinite
- semi-fusinite
- fusinite, and
- micrinite

The volume percent mineral matter is calculated using Parr's formula. The vitrinite reflectance under oil is measured at 750x magnification on a microscope standardized with glass standards of known refractive index.

Microolithotype analysis is based on Stopes Classification using 100 counts for the same pellets used in petrographic analysis. A non-standard procedure was employed as given on pages 257/8 of Stach's Textbook of Coal Rheology, Bointrager, Berlin, 1975.

Ultimate Analysis

Use of a Perkins-Elmer Elemental Analyzer greatly simplified this portion of the work. Carbon, hydrogen and nitrogen were measured with this instrument. Sulfur was also measured, but because of uncertainty in the adequacy of the instrument, measurements were partially repeated with a LECO sulfur Analyzer. Agreement was found to be good so the Elemental Analyzer measurements were used. Oxygen in the coal mineral is obtained from total mass balance.

The carbon determined by the Perkins-Elmer unit includes that present in the organic coal substance as well as that originally present as mineral carbonates. Similarly, the hydrogen includes the hydrogen of the organic coal substance, the hydrogen present in the form of moisture, and the water of constitution of the silicate minerals. Although all of the nitrogen is present as part of the organic coal substance, sulphur occurs as: (1) organic sulphur compounds within the coal structure, (2) pyrite or marcasite FeS_2 , (3) inorganic sulfates. After suitable corrections are made on the data which will account for carbon, hydrogen, and sulphur derived from the inorganic material and for the conversion of ash to mineral matter, an ultimate analysis on a dry ash free basis can be obtained. This represents the elemental composition of the organic portion of the coal matrix.

Computer Blending Program

The problem of formulating a blend of different coal samples to match as closely as possible properties of a target coal was solved by the use of linear programming. In this approach, the difference between blend properties and target coal properties were minimized by choosing the

fraction of each sample the blend is to contain. A necessary assumption is that properties are additive.

If a_1, b_1, c_1 , etc are values of a property i in each sample, g_1 is the property i of the target coal, and x, y, w , etc. are the weight fractions of each sample in the blend, then mathematically the problem is given:

$$\begin{aligned} a_1x + b_1y + c_1w + \dots + M &= g_1 \\ \text{for } i &= 1, 2, 3, \dots \text{ where } 1, 2, 3, \dots = \text{properties} \\ \text{minimize } M, \text{ subject to } x + y + w + \dots &= 1 \end{aligned}$$

This can be implemented using a variety of LP computer programs. For this study a Waterloo Computer Library program LP1 (version 2) was utilized. Appendix F gives program input, namely the function $a_1x + b_1y + c_1w + \dots + m g_1$, and the output.

EXPERIMENTAL RESULTS AND INTERPRETATION

Part I

This portion of the project investigated the importance of different aging rates on the rheology of the western Canadian and Appalachian coals.

Aging: Dilation and contraction measurement in the Ruhr Dilatometer appear to be good indicators of aging. Total dilatation (c+d) for the western Canadian coals obtained with the Ruhr instrument over a three-month period are shown in Figures 7 to 9. Figure 7 is based on 4 data points for each time interval. Measurements with each coal were replicated, however, for the WC4 coal two separate samples were used. This provided a means of checking reproducibility of the dilatometer and the sampling procedures. The agreement of these completely independent data sets was generally good. Total dilatation under DIN standard conditions are the bottom curves in Figure 7 to 9. There is an increase of about 10% for the WC4 coal which is barely significant given the variability at each time interval, whereas

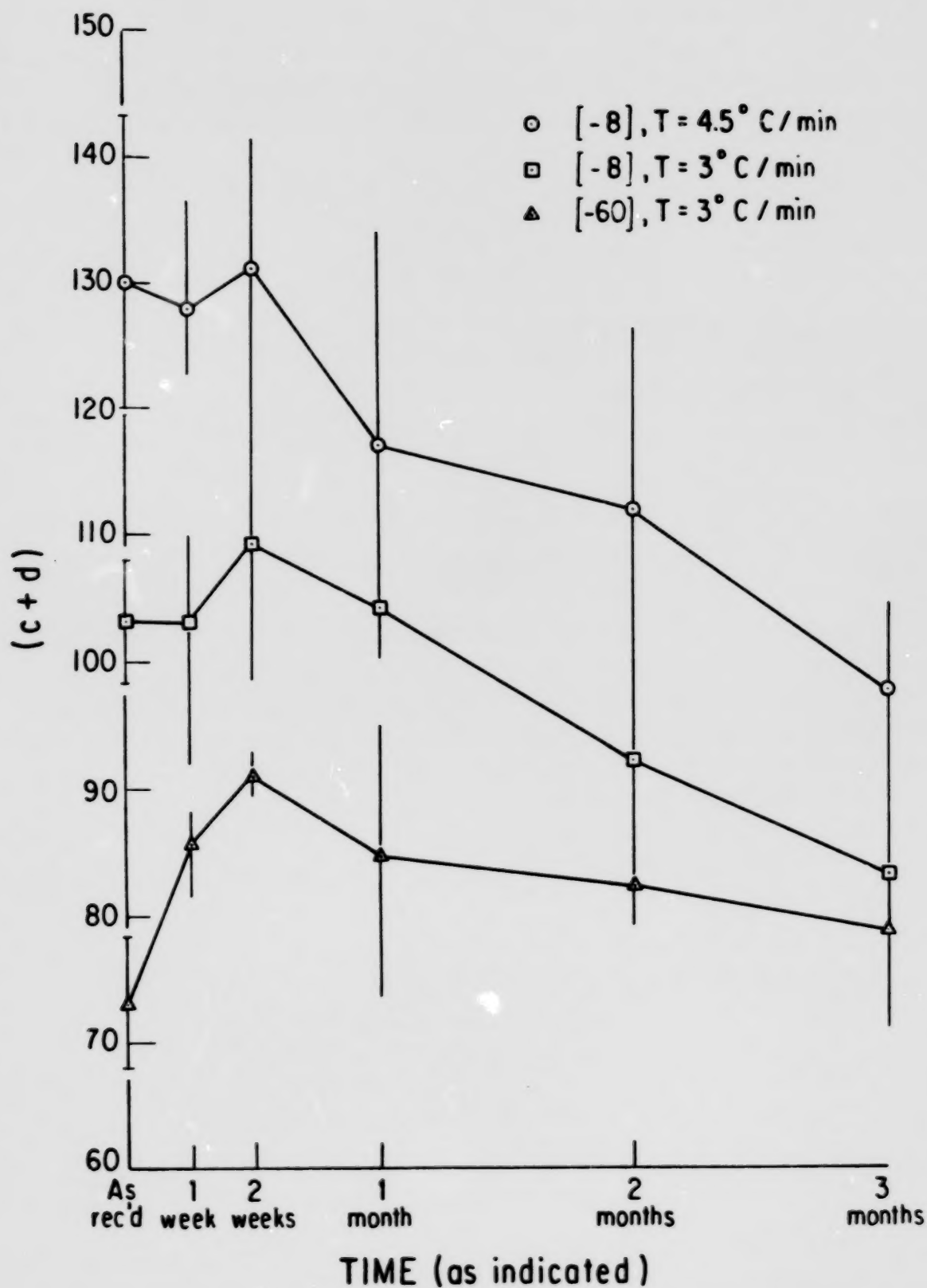


Figure 7 Aging Study: Total Dilatation for WC4 Sample (Clean)

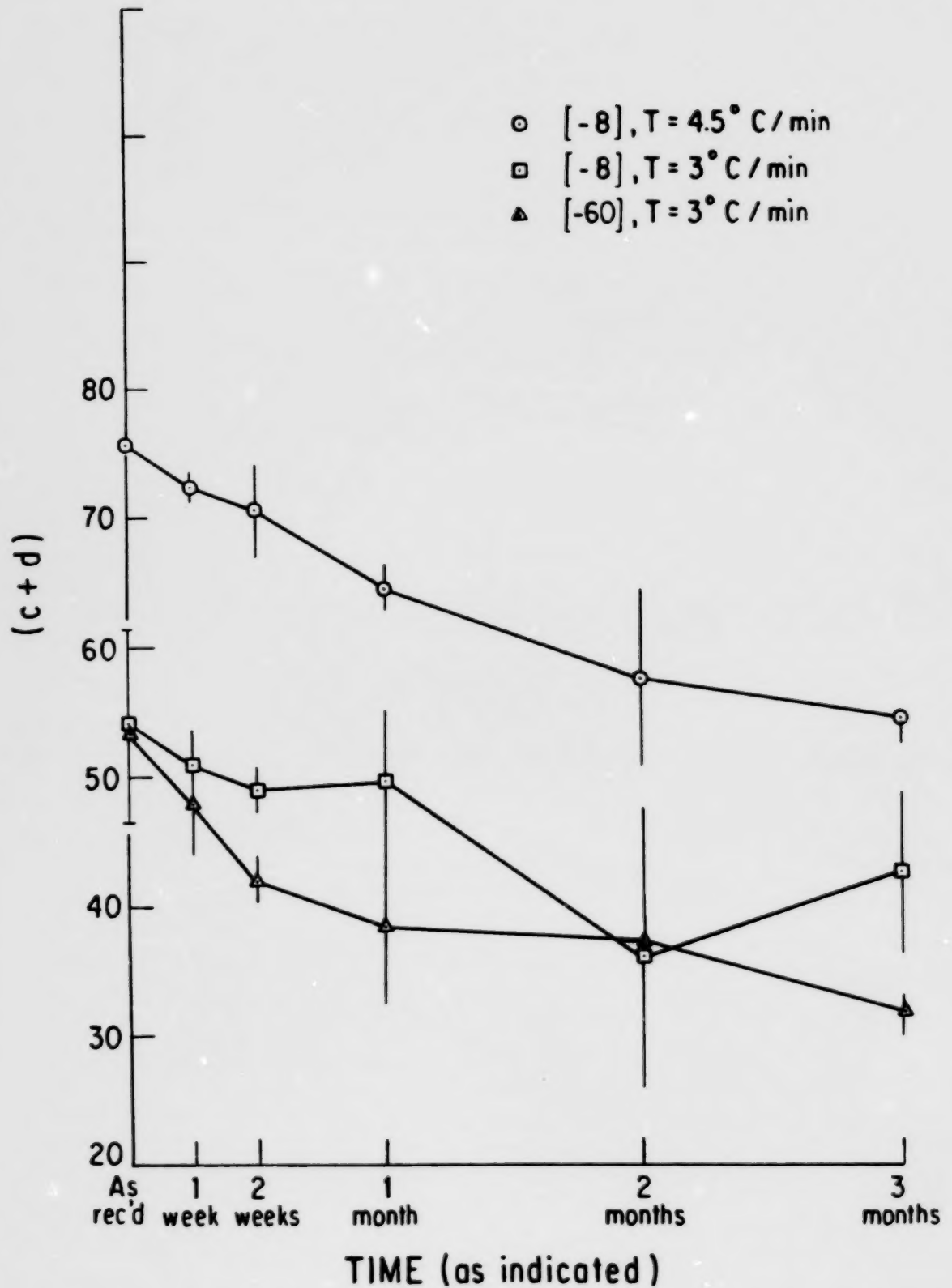


Figure 8 Aging Study: Total Dilatation for WC5 (Raw)

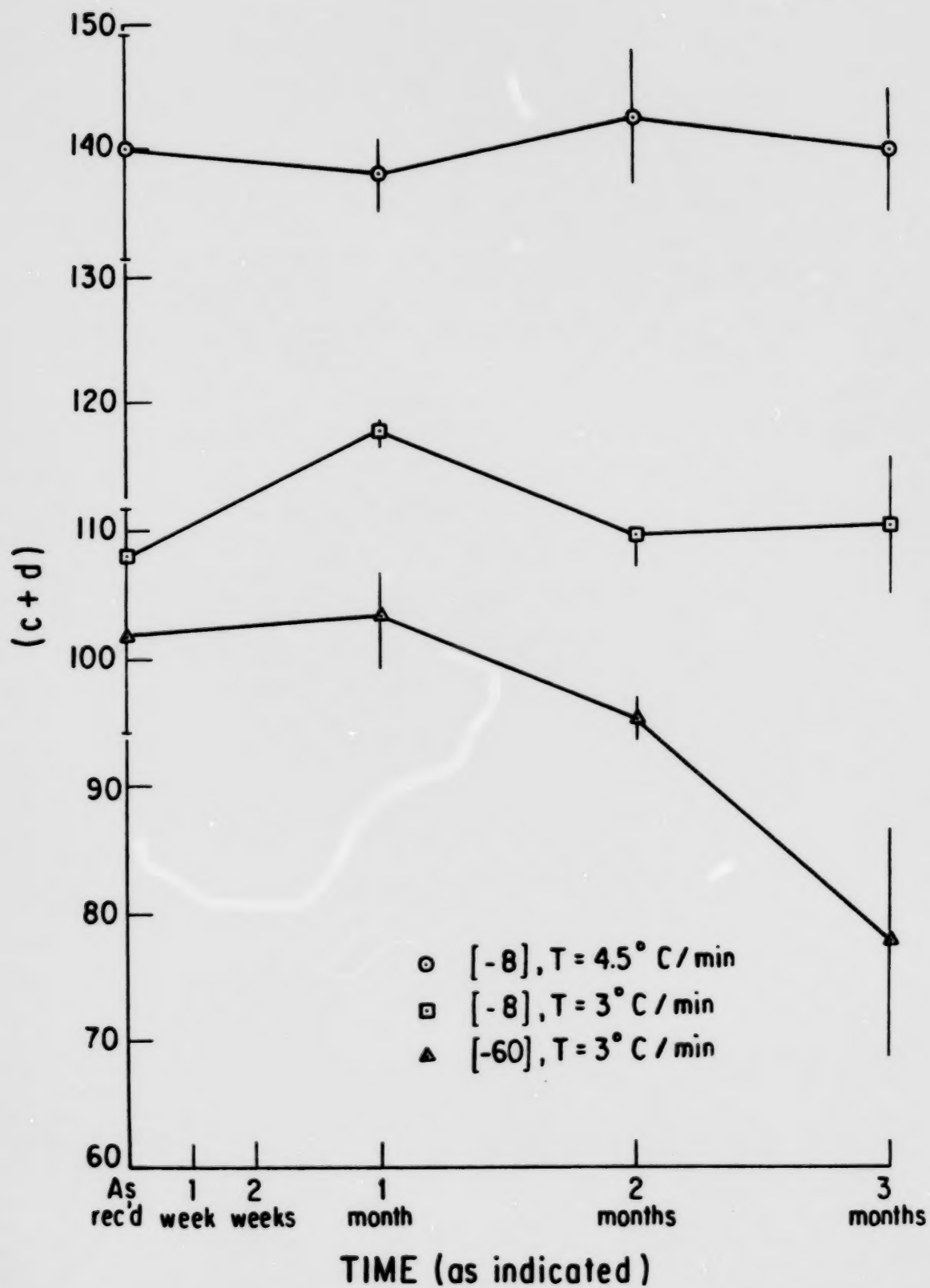


Figure 9 Aging Study: Total Dilatation for WC6 (Raw)

there is a large significant 40% decrease for the WC5 coal, and a 25% decrease for the WC6 coal.

Under non standard conditions, the picture changes. There is a 30% decrease in $c + d$ for the WC5 coal, whereas for the WC6 coal there is no significant change. For the WC6 coal, the decrease is the same for both standard and non-standard conditions.

Measurements for the WC4 coals show considerably more sample to sample variation for non standard measurements than for those made under standard conditions. However, this difference is not supported by the WC5 or the WC6 coals. For those latter coals, it appears that the shift from -60 to -8 mesh samples has just a small effect on total dilatation. Heating rate is the dominant variable.

Closer examination of the dilatometer results (see Table A1) shows that aging affects dilatation (d), but contraction (c) varies very little with time. Indeed, heating rate changes for the three western Canadian coals does not change c, only sample top size seems to change the values registered. Consequently, the loss in total dilatation is attributable solely to changes in (d). Furthermore, heating rate and sample top size are major variables in (d).

Figures 10 to 12 show the change in $c+d$ for the Appalachian coals. The first two figures present data for the AC3 raw and clean coals respectively. Cleaning effects, of course, the absolute dilatation values, but comparison of the figures show that the trends are similar. Total dilatation for the AC3 sample appears to increase by about 66% for the raw coal and about 10% for the clean coal when dilatometry according to the DIN standards are used. Based on sample to sample variation, the latter change is statistically significant. An increase in total dilatation with time does not make sense so the observation can only be attributed to sampling variation. It is surprising that the two samples for the AC3 raw coals are so close together. The slight increase in $c+d$ under DIN standard conditions over three months for the AC4 coals is not statistically significant.

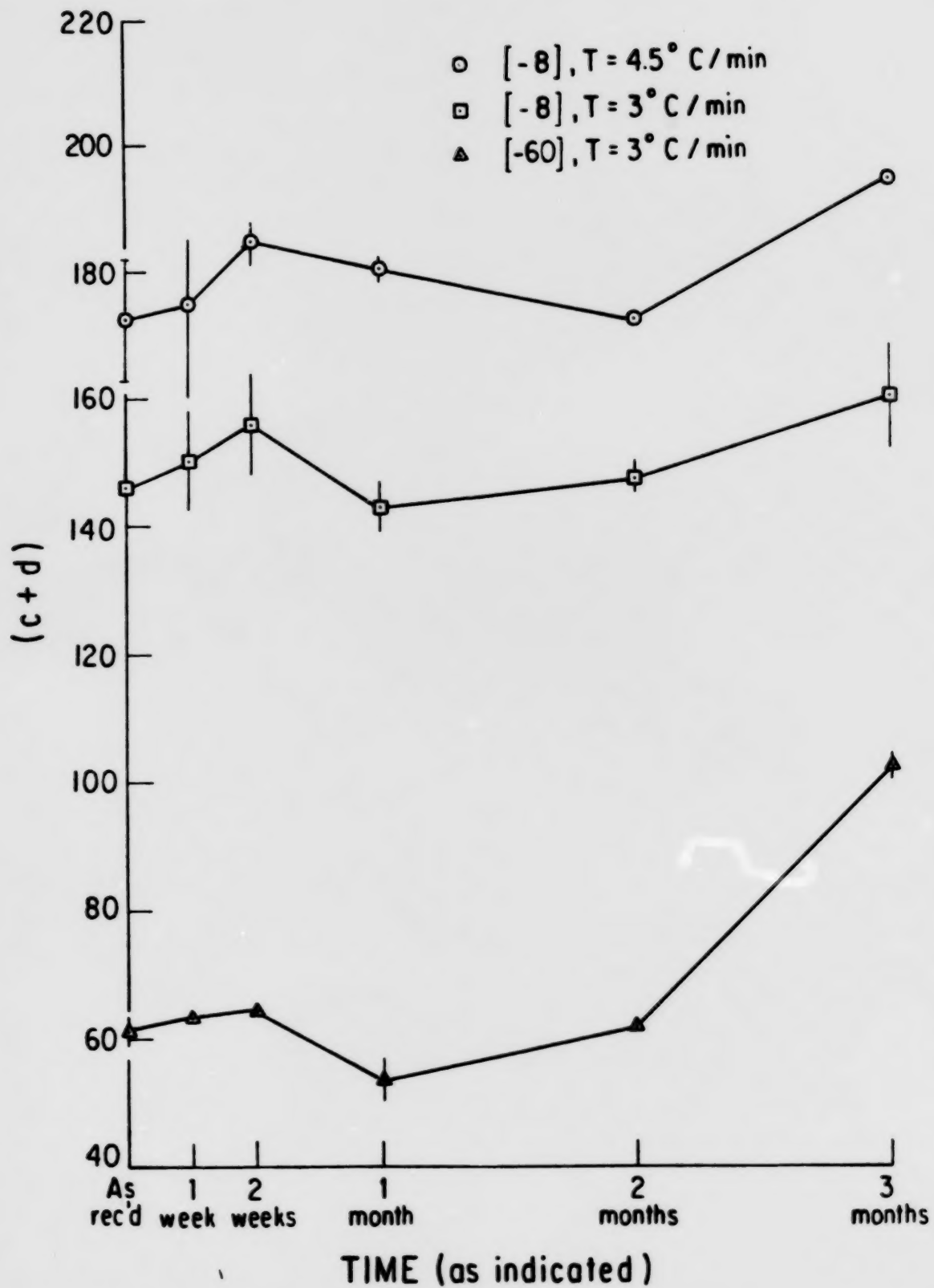


Figure 10 Aging Study: Total Dilatation for AC3 (Raw)

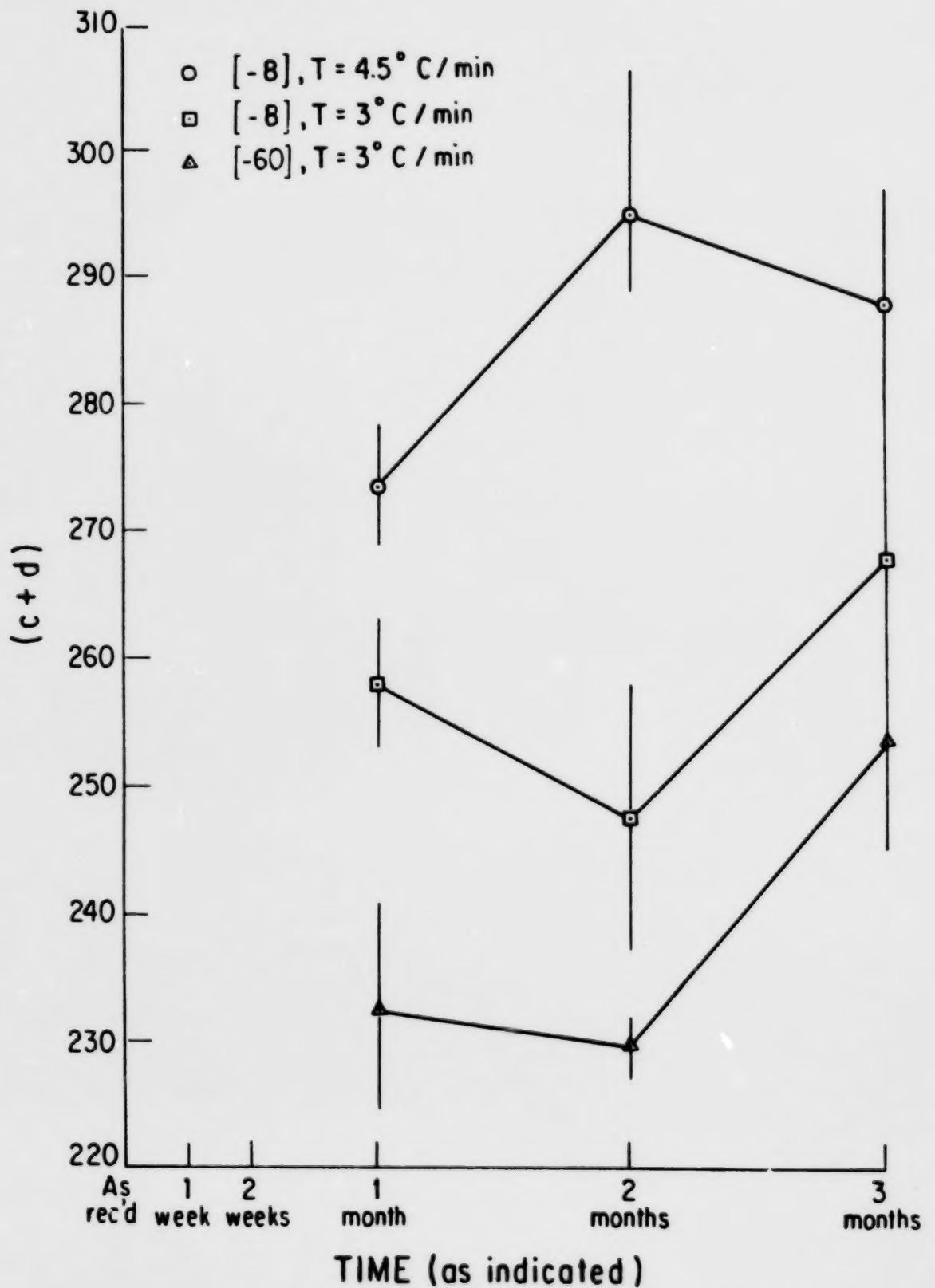


Figure 11 Aging Study: Total Dilatation for AC3 (Clean)

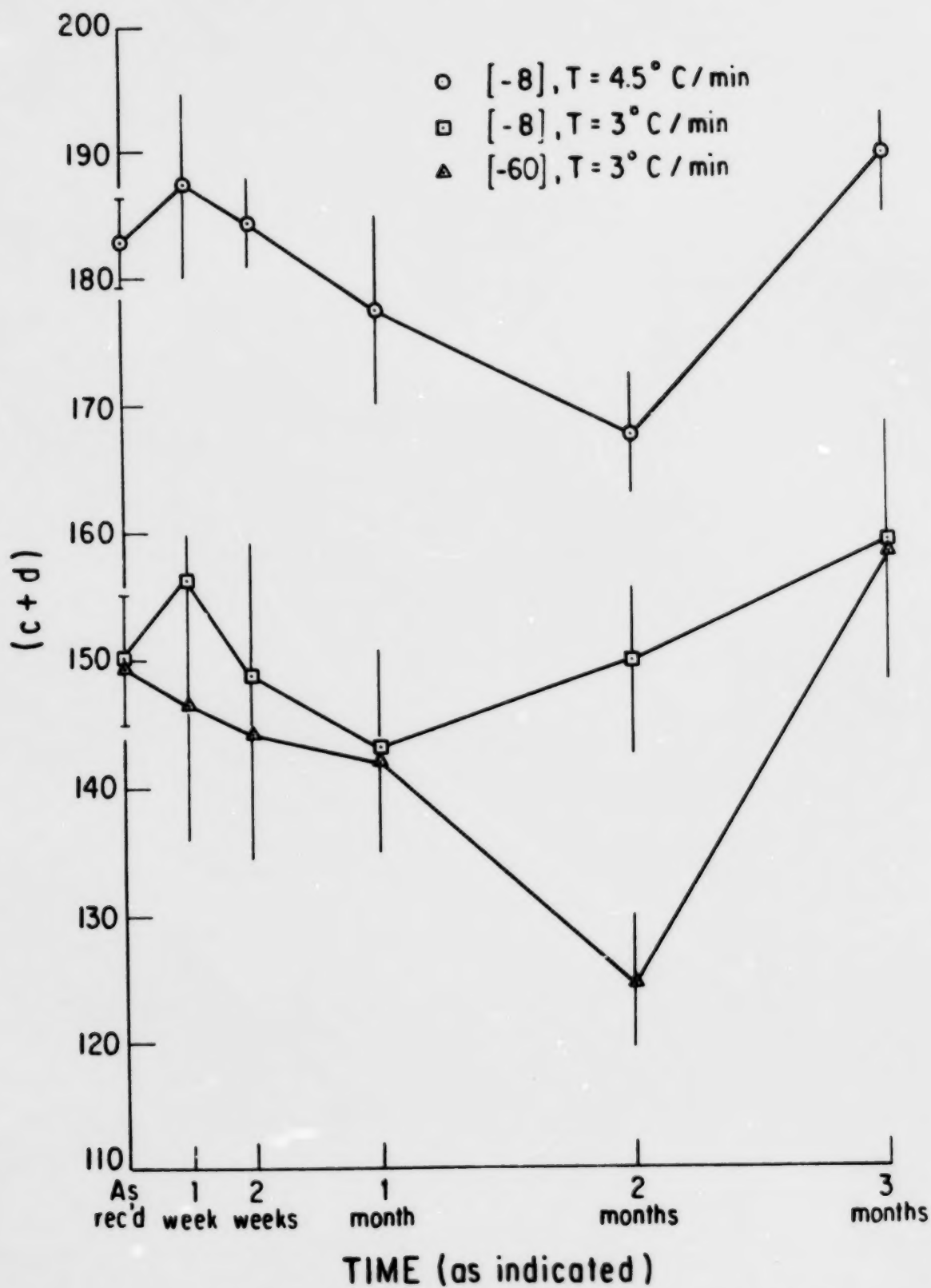


Figure 12 Aging Study: Total Dilatation for AC4 (Raw)

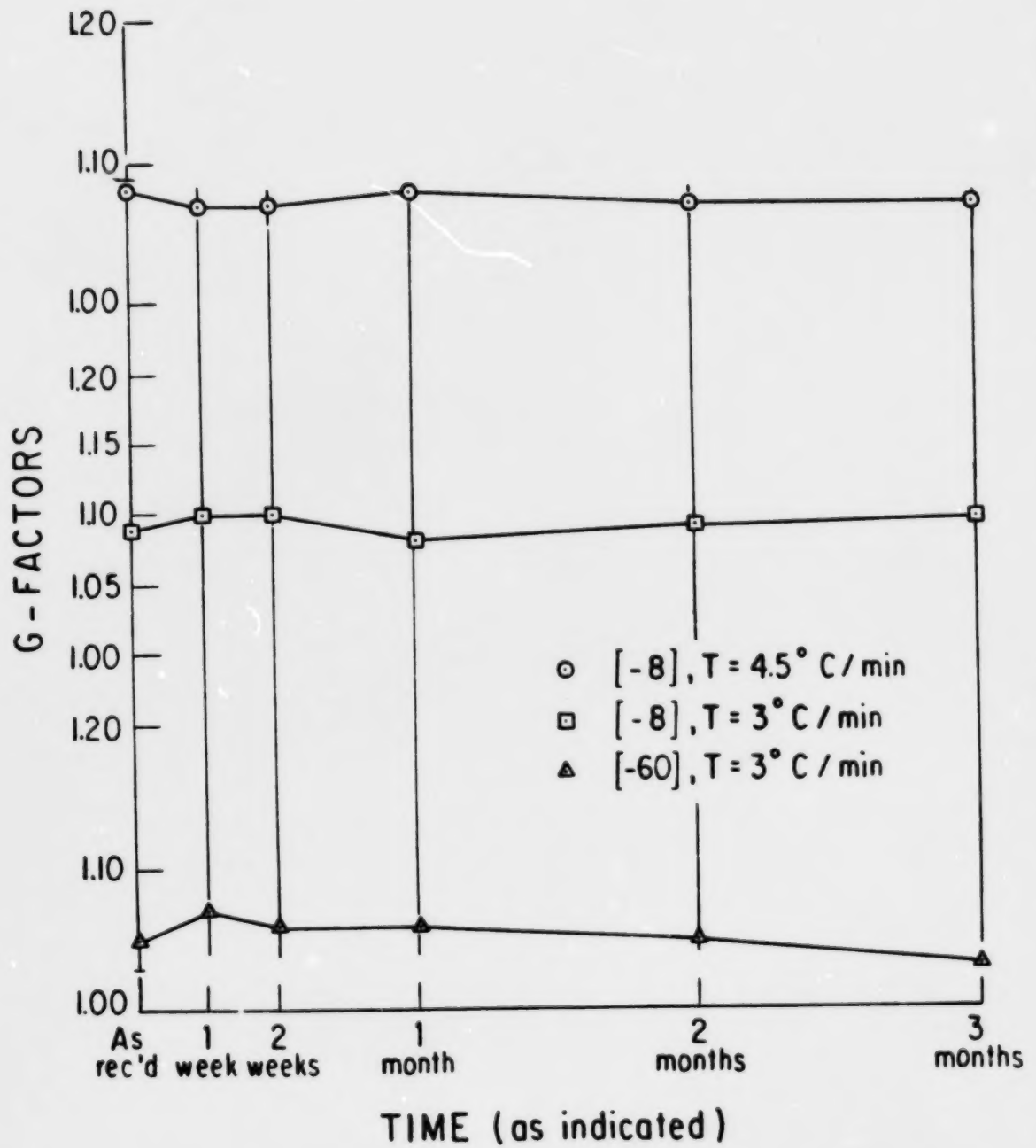


Figure 13 Aging Study: G-Factors for WC4 Coal (Clean)

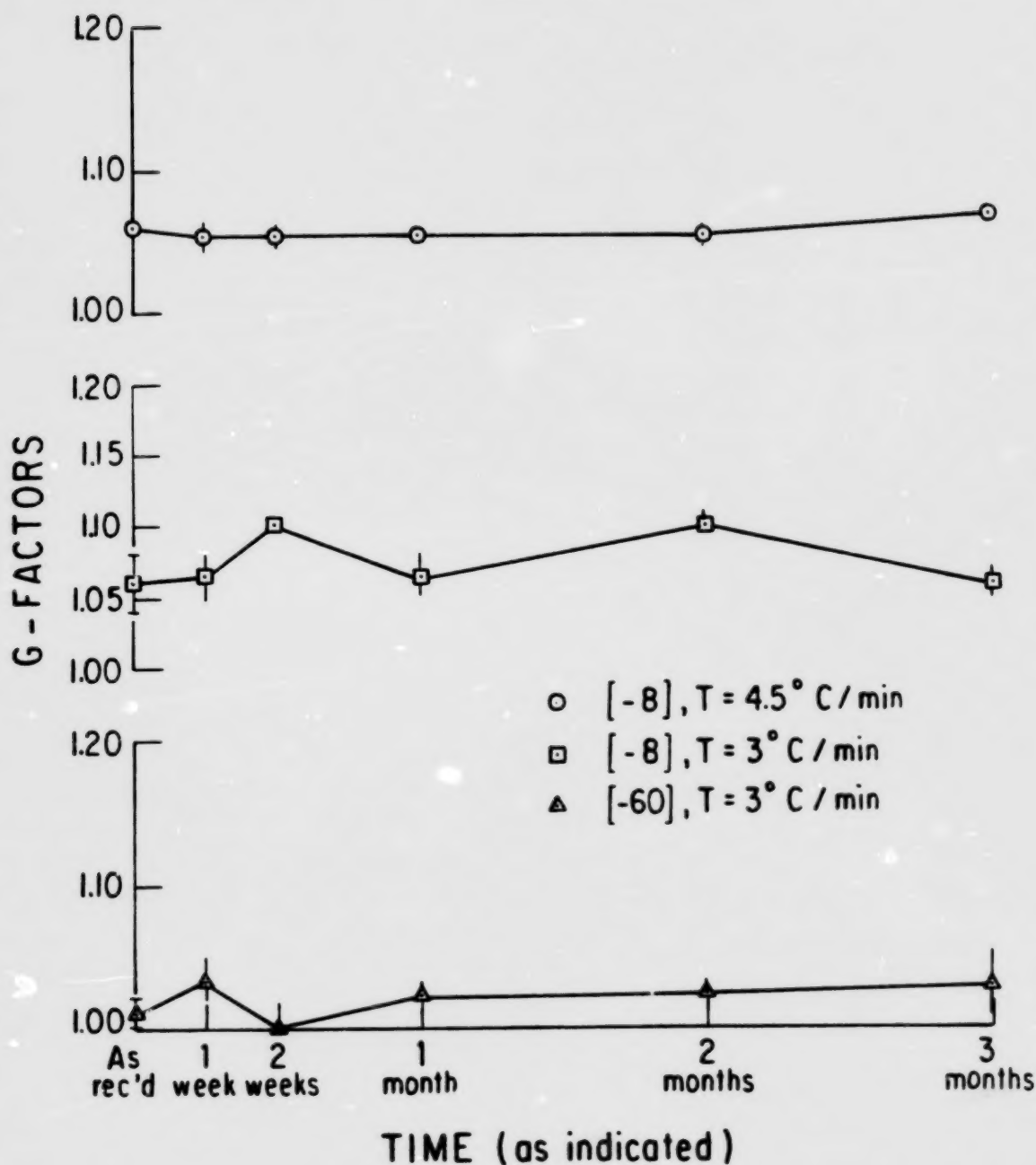


Figure 14 Aging Study: G-Factors for WC5 Coal (Raw)

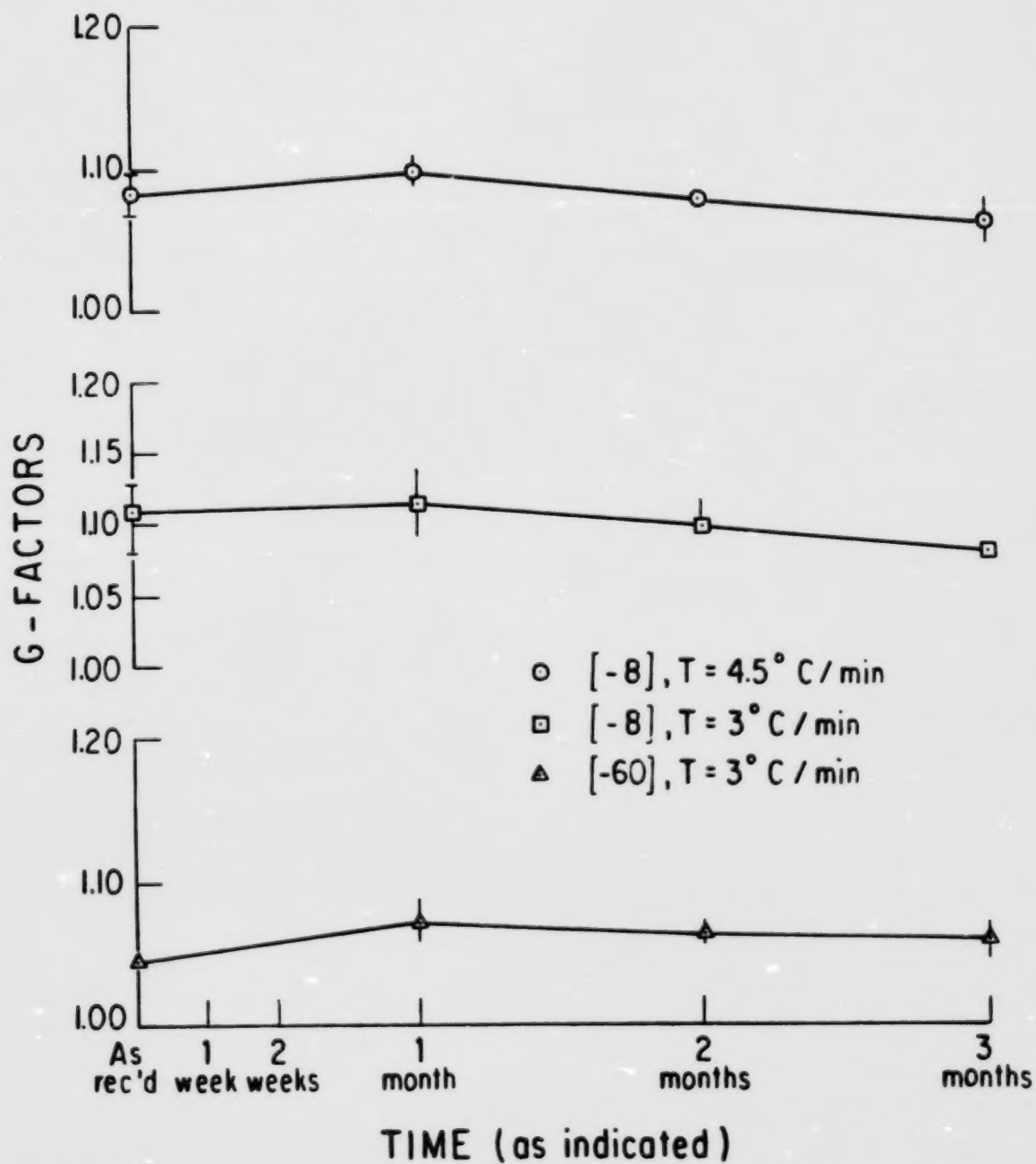


Figure 15 Aging Study: G-Factors for WC6 Coal (Raw)

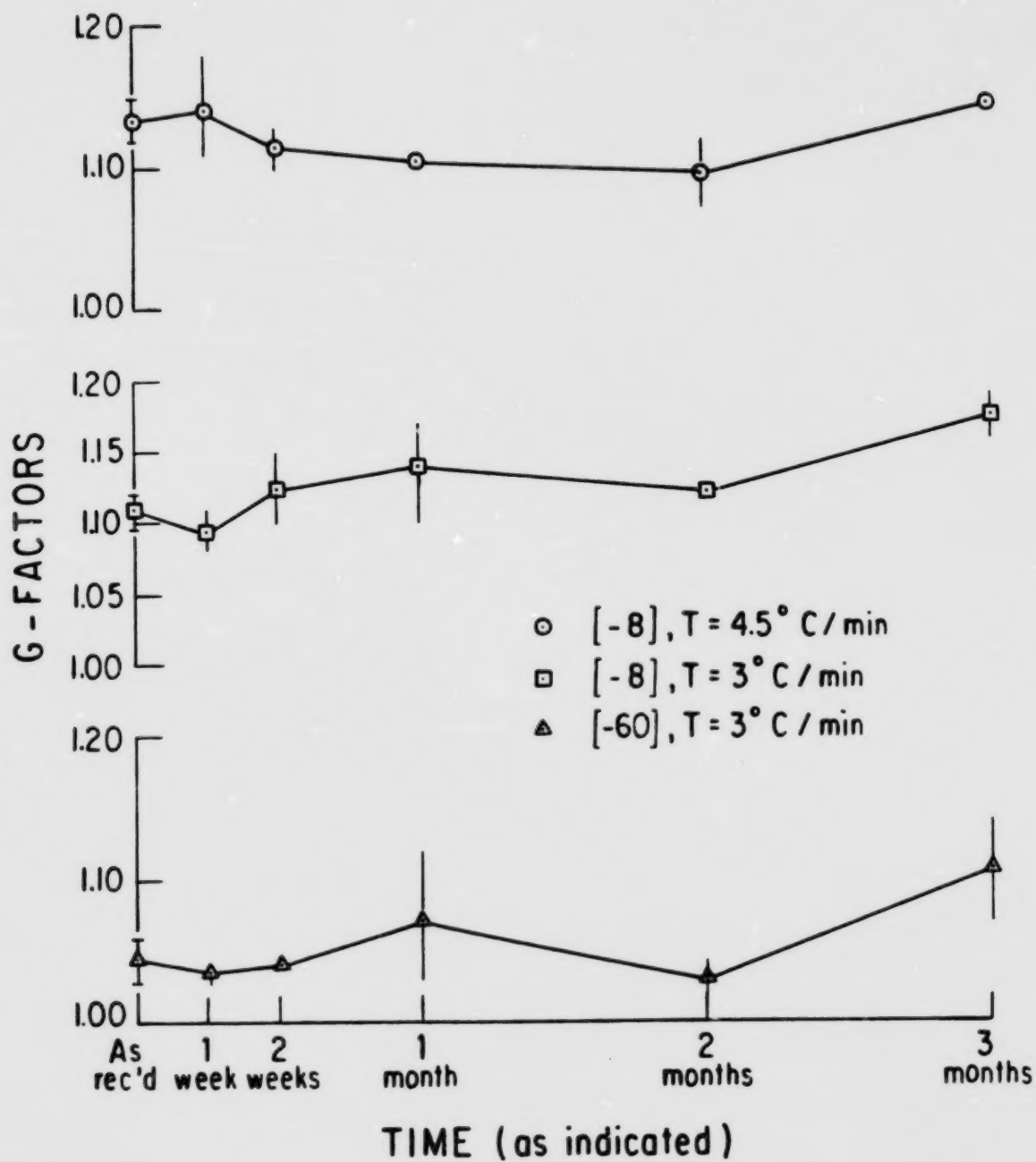


Figure 16 Aging Study: G-Factors for AC3 Coal (Raw)

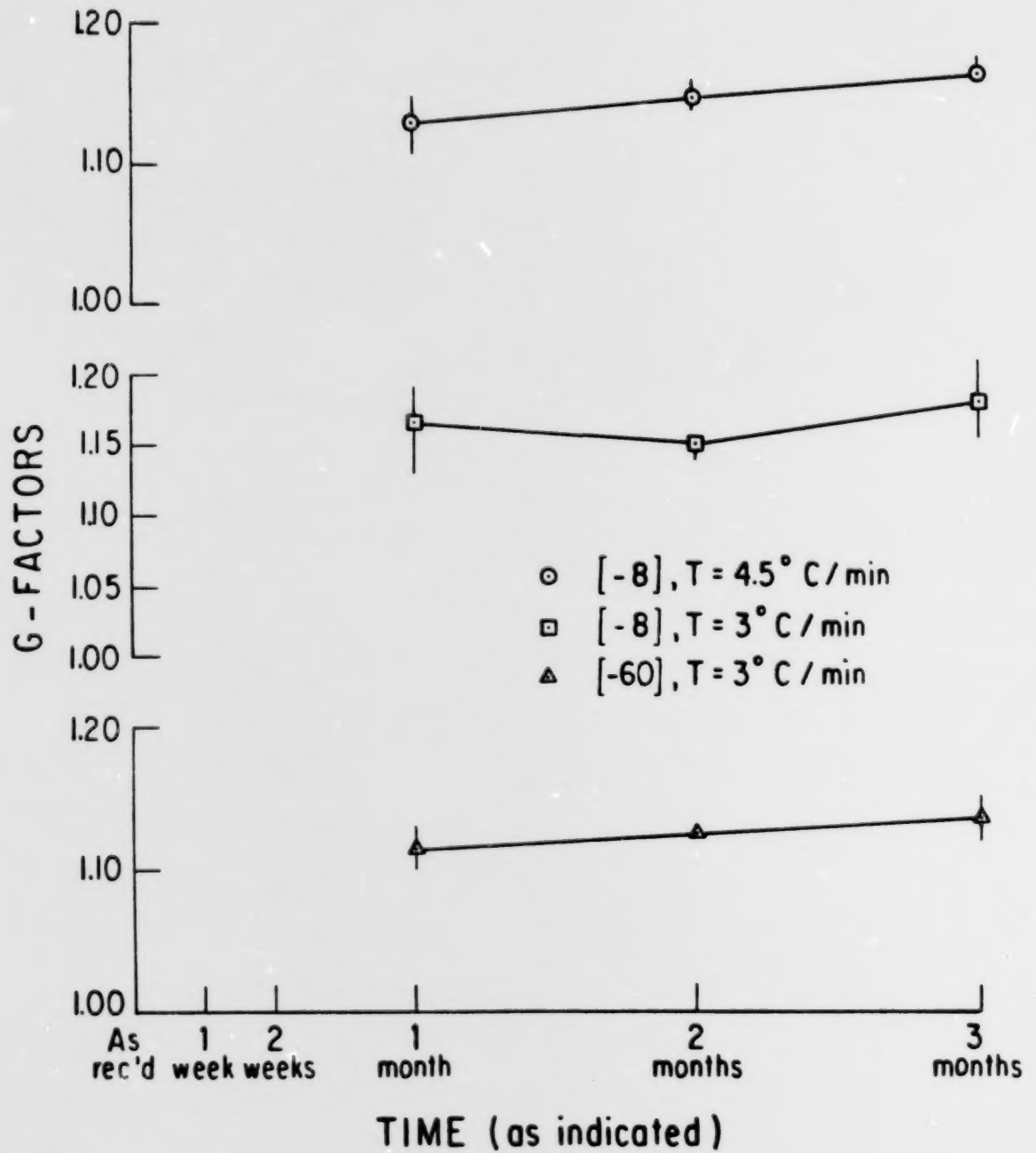


Figure 17 Aging Study: G-Factors for AC3 Coal (Clean)

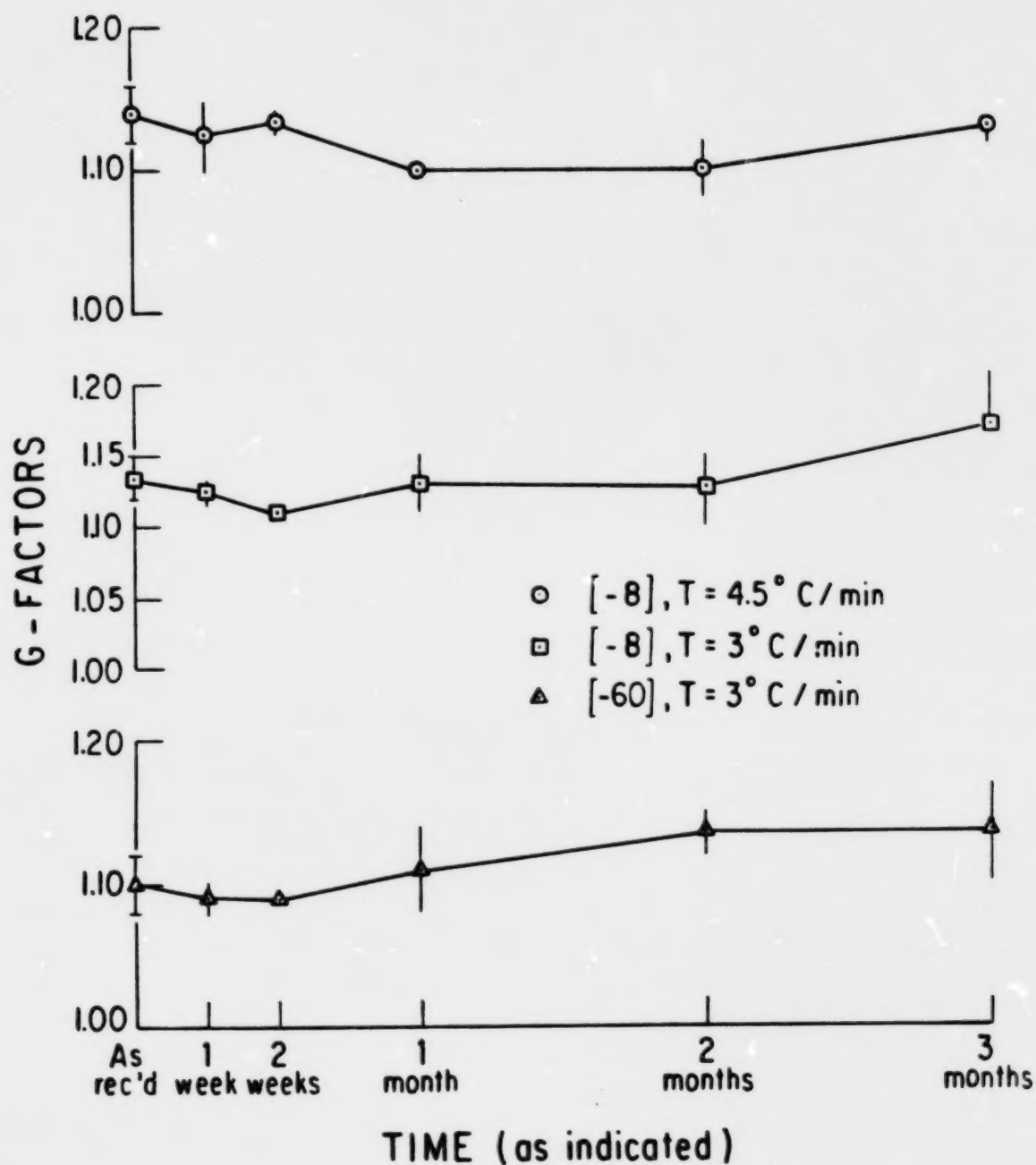


Figure 18 Aging Study: G-Factors for AC4 Coal (Raw)

For the non standard test conditions, the AC3 raw coals shows about a 13% increase, which is significant. The small increase for the clean AC3 coal, however, is just barely significant. For the AC4 coals, there is once again a small increase which is not statistically significant at the 95% confidence level used for testing.

Considering the curious, irregular changes in total dilatations with time (e.g. Figure 11), it would seem that large sample to sample variations must be occurring with the Appalachian coals. Aging must be negligible over the three month period for these coals.

Detailed examination of the Appalachian data shows a behaviour similar to the western Canadian coals. Aging is unimportant for contraction and the main variable in this measurement is sample top size. Largest time variations occur for and test conditions exert the greatest effect on d.

Aging was also examined from the aspect of the G factor defined as:

$$G = \left(\frac{T_1 + T_3}{2} \right) \times \left(\frac{c + d}{c \times T_3 + d \times T_1} \right)$$

where c = max. contraction, d = max. dilatation, T_1 = softening Temp., T_2 = temp. at max. contraction, T_3 = temp. max. dilatation. Of course, this factor is widely used to rate the coking propensity of coals. As may be seen, the factor uses temperature as well as dilatation and contraction measurements.

Figures 13 to 18 plot the G-factor against time for the various coals tested at the three experimental conditions used in the dilatometer test. It is evident that the G-factor is not a sufficiently sensitive parameter for explorations of aging effects. Whereas total dilation showed a strong aging effect for the WC4 coal under non-standard conditions, Figure 13 shows no statistically significant variation in G over the 3 months for the coal. The DIN standard data show a slight, statistically significant decrease for G, while c + d increases. For the WC5 coal, G-factors do not

change in time regardless of test conditions. Again, for the WC6 coal the observed $c + d$ decline under DIN standard conditions disappears when G-factors are used. On the other hand, the G-factors for the Appalachian coals reflect the trends observed in the $c + d$ data, but the differences are suppressed and the uneven record with time disappears. In almost all cases, the changes are not statistically significant at a 95% confidence level.

Examining the temperatures in Table A1, it is evident that temperature changes are opposite to the $c + d$ changes for the western Canadian axis. This makes the G Factor insensitive to modest aging for western Canadian coals.

Whereas, for the Appalachian coals aging has changed temperatures just slightly so the dominant effect is $c + d$. The G-factor results then mirror what has been observed with the total dilatation measurements.

It appears then that dilatation or total dilatation is the best indicator of aging changes in both western Canadian (Cretaceous) and Appalachian (Carboniferous) coals.

Despite the different indications based on $c + d$ and G-factor for the western Canadian coals, it seems that aging does occur to a significant extent with these coals. On the otherhand, aging over the 3 month period is negligible for the Appalachian coals. Even though differential aging of the coals must be considered as a factor in comparing the rheology of the western Canadian and Appalachian coals, it cannot account for all the differences observed. Aging may partially explain why the western Canadian coals differ from the AC3 coal, but it cannot explain the large difference between, say, the WC8 and AC4 coals.

Table 3
Comparison of Test Coals

Property	Coal				
	WC4	WC5	WC6	AC3	AC4
Fixed Carbon % db daf	69.1	74.9	71.5	69.1	72.0
Ash % db	25.0	8.41	8.0	29.7	17.9
Sulfur % db	1.77	1.53	1.05	1.21	0.57
Reactive Macerals					
Vitrinite %	68.0*	40.6	74.5	57.0	40.9
Semi-Fusinite %	4.5*	19.0	4.2	1.9	4.7
Exinite %	0.9	0	0	3.6	5.7
Inert Macerals					
Semi-Fusinite %	9.1*	19.0	8.5	3.9	9.4
Fusinite %	4.1*	10.9	4.5	4.2	7.9
Micrinite %	10.5*	5.5	1.6	10.0	20.9
Mineral Matter %	2.9*	5.0	4.6	18.8	10.5
Reflectance (Random)	1.05*	1.08	ND	1.05	1.07
(Maximum)	1.08	1.14	1.20	1.05	1.12
Total Dilatation c+d**	78.0*	77.0	32.0	102.0	158.0
Maximum Fluidity ddpm	12	84	135	4512	3345
Free Swelling Index	4	8	7.5	6	8.5

* Only data for cleaned coal available

** After 3 month data

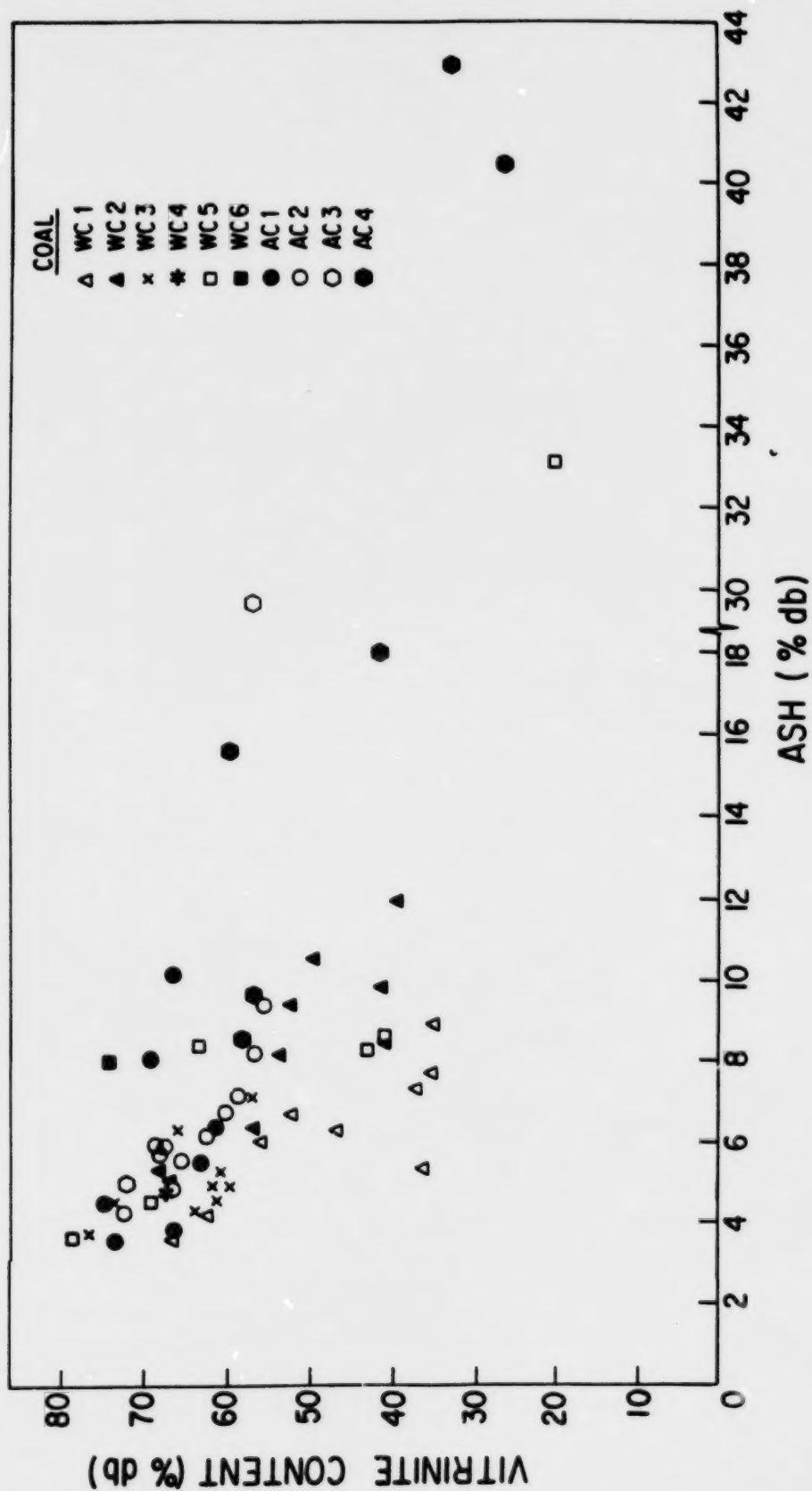


FIGURE 19 VITRINITE VS. ASH CONTENT IN THE 19 WESTERN CANADIAN AND APPALACHIAN BITUMINOUS COALS

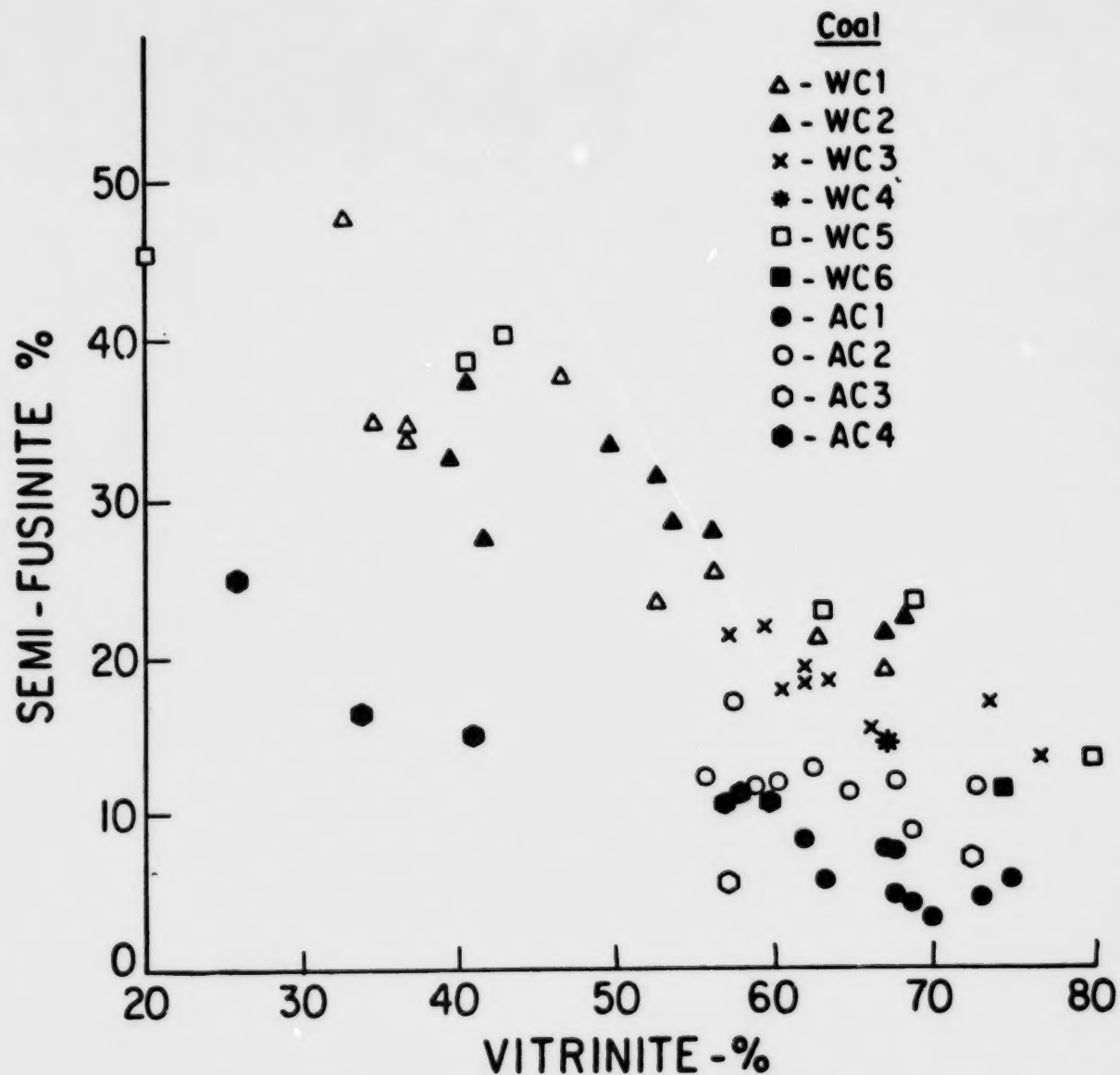


FIGURE 20 SEMI FUSINITE VS. VITRINITE CONTENT IN THE COALS STUDIED

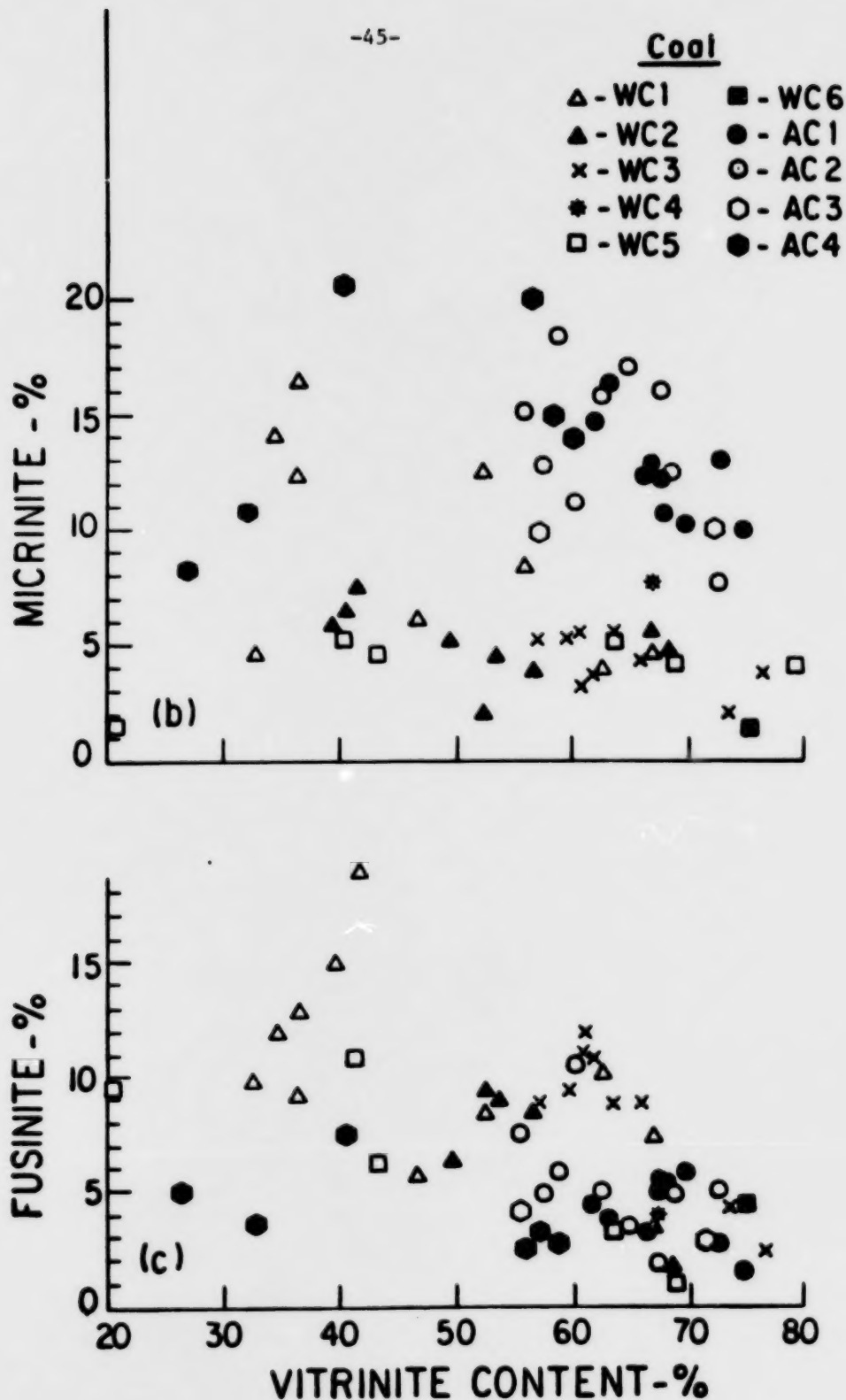


FIGURE 21 OTHER MACERALS VS. VITRINITE CONTENT IN TEST COALS

PART II - COAL BLENDING FOR IMPROVED RHEOLOGY

Choice of Coals for Part II

Criteria for the western Canadian and Appalachian coals to be chosen for Part II were that the coals should have equal rank, good coking potential, nearly equal reflectance, and ash. The western Canadian coal should be eu-plastic, at least. Fortunately, all the western Canadian coals filled the latter criterion and as may be seen from Table 3 the best match are the WC5 and AC4 coals. Reflectance of these coals is close and both are high enough to suggest good coking properties. Vitrinite contents were also close. Only the ash mineral matter and sulfur values were widely separated. A second possible match was the WC4 and AC3 coals. This set was not chosen because of the low reflectances of these coals. Vitrinite content was also substantially different.

RESULTS OF SIEVE/FLOAT-SINK ANALYSES

Maceral Composition

Our final report submitted in 1983 on the first phase of this project (Waterloo Centre for Process Development, 1983) compared the maceral composition of the western Canadian and Appalachian coals. The comparison are updated with the maceral compositions of the five coals examined in the current contract. Unlike the five coals examined in the first phase, sequential float-sink separation was undertaken on just two of the five coals, so this year's data is much less extensive.

Figure 19 shows the increase in the vitrinite content as the specific gravity of the float-sink media decreases. The data for the WC4 to WC6 and AC3 and AC4 coals examined in this year's contract fall in the span of data obtained last year. Slopes are larger for the western Canadian coals than for the Appalachian coals even though the range of ash content overlaps for these geographically different coals. Slope difference suggests the

Effect of Non standard Test Conditions on Rheology

Data obtained in Part I with respect to dilatometer test conditions are collated in Table 4. These data confirm the observation made in our previous report (Waterloo Centre for Process Development, 1983) and by Ramachandran (1984) for the western Canadian coals, namely that increasing top size from [-60] mesh to [-8] mesh substantially increases total dilatation while increasing heating rate to 4.5°C/min. from 3°C/min has an even larger effect. Table 4 shows that the same observations can be made for the Appalachian coals. Unlike our previous findings, the fractional increases of total dilatation for the western Canadian and Appalachian coals are about equal, whereas last year's data suggested the absolute increases in total dilatation were about equal, but the fractional increase was much larger for the western Canadian coals. Additional runs were made with [-60] mesh samples, but with the fine [-100] mesh material removed. These results, which are also shown in Table 4, suggest that it may be the fine [-100] mesh material that inhibits contraction and dilatation. The main effect of raising the top size to [-8] mesh is reducing the fraction of [-100] mesh in the sample. It is the second, third and fifth columns in Table 4 which support this observation. With the exception of the WC5 sample, the c + d values at [-8] mesh and [-60 x 100] mesh are similar. Increasing the heating rate for the [-60 x 100] mesh samples to 4.5°C/min produces increases in c + d which are close to the increases observed with the [-8] mesh samples when the heating rate was raised.

The western Canadian coals used in this year's work were all at least eu-plastic under standard Ruhr dilatation operating conditions, whereas in the previous year some of the coals were sub-plastic.

Figure 22 reproduces a cross plot of total dilatation under standard and non standard conditions of the western Canadian coals from our previous report (Waterloo Centre for Process Development, 1983) on which some of the data taken in parts I and II have been added. The previous observations are confirmed by this new data. Both increased top size and heating rate raise total dilatation. The largest absolute increases occur, in general,

inertinite minerals are preferentially removed in the sink-float separations for the western Canadian coals.

In our previous report (Waterloo Centre for Process Development, 1983), the striking differences in the semi-fusinite to vitrinite ratios were pointed out. Figure 20 now includes the data for the WC5 and AC4 coals (as well as points for the raw coal and clean coal of the other samples). These confirm our previous observations. It can be seen that the WC and AC coals form quite distinct populations with no overlap. The change in semi-fusinite content as vitrinite changes is a measure of the effect of cleaning. The greater slope for the WC data appears to suggest significantly higher semi-fusinite removal with cleaning than that observed for Appalachian coals. If one determines the fractional change in semi-fusinite for the same change in vitrinite (for example between 30% and 70% vitrinite), these fractional changes are about the same. The differing slopes reflect therefore, the large difference in the semi-fusinite to vitrinite ratio, and not enrichment or depletion in cleaning.

Figure 21 shows the updated plots for vitrinite and fusinite. Exinite levels are small and the measurement error high so that a plot of the data is not useful. The percent vitrinite (Figure 21) data separate sharply by coal source. Unlike the semi-fusinite data, the Appalachian coals have significantly higher micrinite levels than the western Canadian coals. Note that the raw coal data and the first sink sample overlap the Western Canadian data. Some differences in slope appear but these probably reflect levels rather than preferential separation in float-sink separation.

Some separation of the fusinite data is evident in the fusinite versus vitrinite plot (Figure 21b). Western Canadian coals appear to be richer in this maceral. Floating of the coals reduces fusinite, however, to about the same level for both western Canadian and Appalachian coals. The trends with ash removal seem to vary considerably among the samples in each geographical group.

Table 4

Comparison of Dilatometer Results for Western Canadian and Appalachian Coals

COAL	Standard DIN (c+d)	G-factor	[-8]; T=3°C/min (c+d)	G-factor	[-8]; T=4.5°C/min (c+d)	G-factor	[-60x100]T=3°C/min (c+d)	G-factor	[-60x100]T=4.5°C/min (c+d)	G-factor
WESTERN CANADIAN										
WC6 (R/C)	77.3	1.06	110.1	1.08	139.8	1.07	97.9	1.09	122.9	1.07
WC5 (R/C)	31.6	1.03	42.7	1.06	54.5	1.07	9.0	1.01	12.4	1.00
WCA (C/C) Sample 1	77.2	1.03	72.8	1.07	92.4	1.07	72.1	1.07	91.9	1.05
Sample 2	79.8	1.04	92.9	1.13	102.5	1.07	86.9	1.06	102.8	1.07
APPALACHIAN										
AC3 (C/C)	253.6	1.14	267.8	1.18	288.1	1.16	261.3	1.12	290.0	1.15
AC3 (R/C)	101.8	1.10	160.1	1.18	194.5	1.14	147.4	1.12	156.6	1.11
AC4 (R/C)	158.4	1.13	159.2	1.17	189.3	1.13	176.2	1.10	201.6	1.10

All values are from "after 3 month" samples and are averages of two measurements.

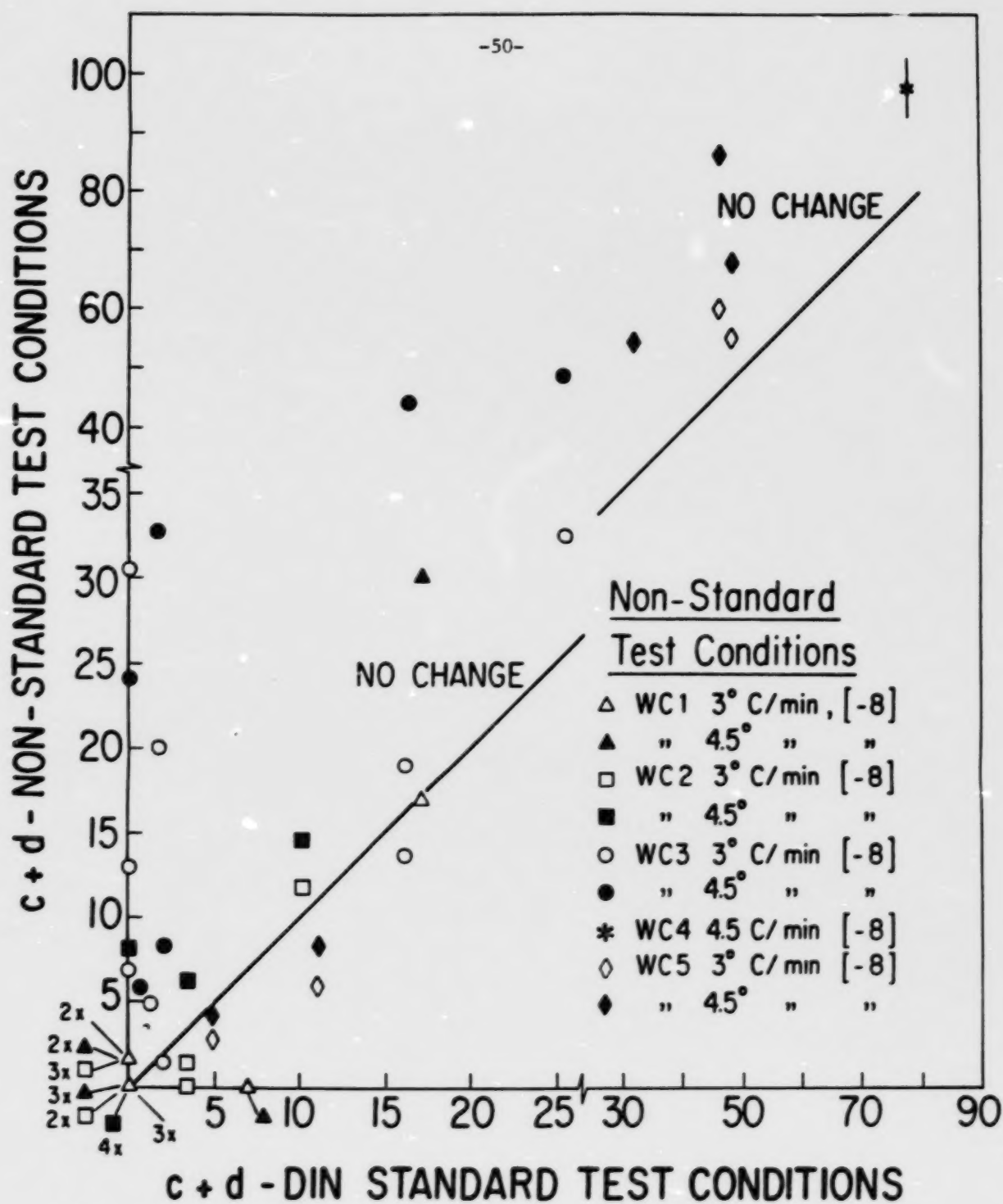


FIGURE 22 USE OF TOTAL DILATATION TO ASSESS THE INFLUENCE OF TEST CONDITION CHANGES FOR WESTERN CANADIAN SAMPLES

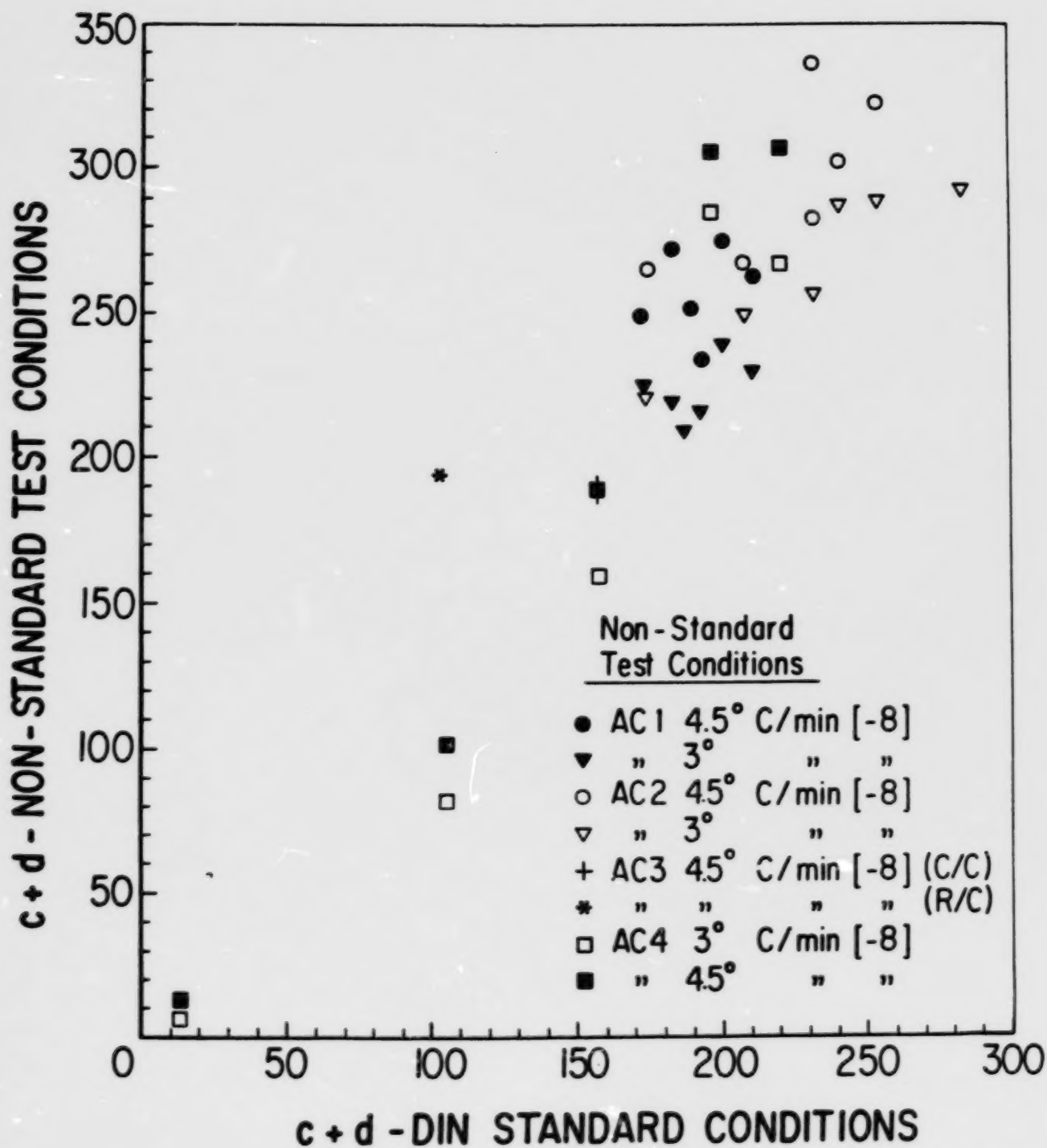


FIGURE 23 USE OF TOTAL DILATATION TO ASSESS THE INFLUENCE OF TEST CONDITION CHANGES FOR APPALACHIAN COALS

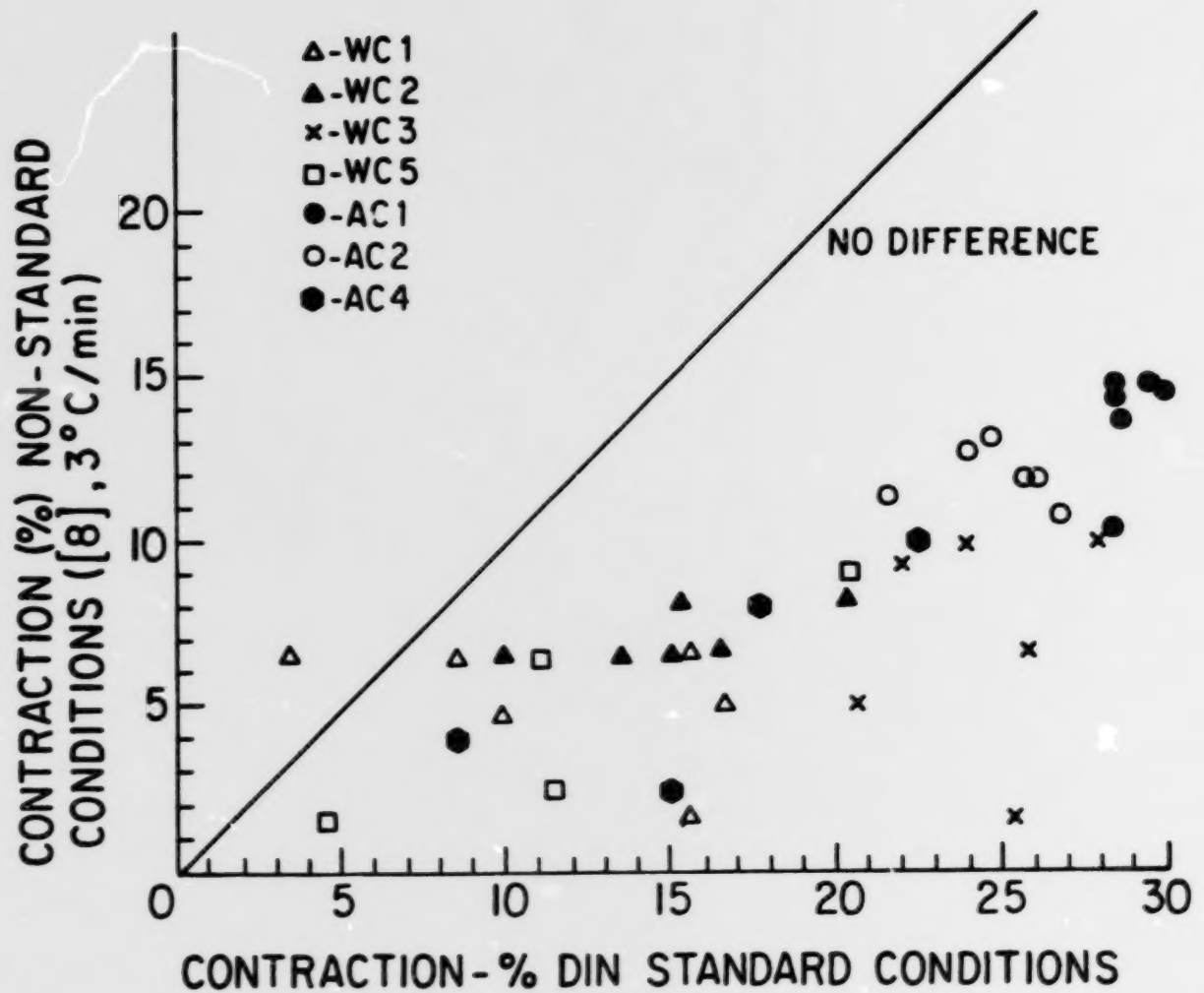


FIGURE 24 USE OF CONTRACTION TO ASSESS INFLUENCE OF TEST CONDITIONS ON RHEOLOGY

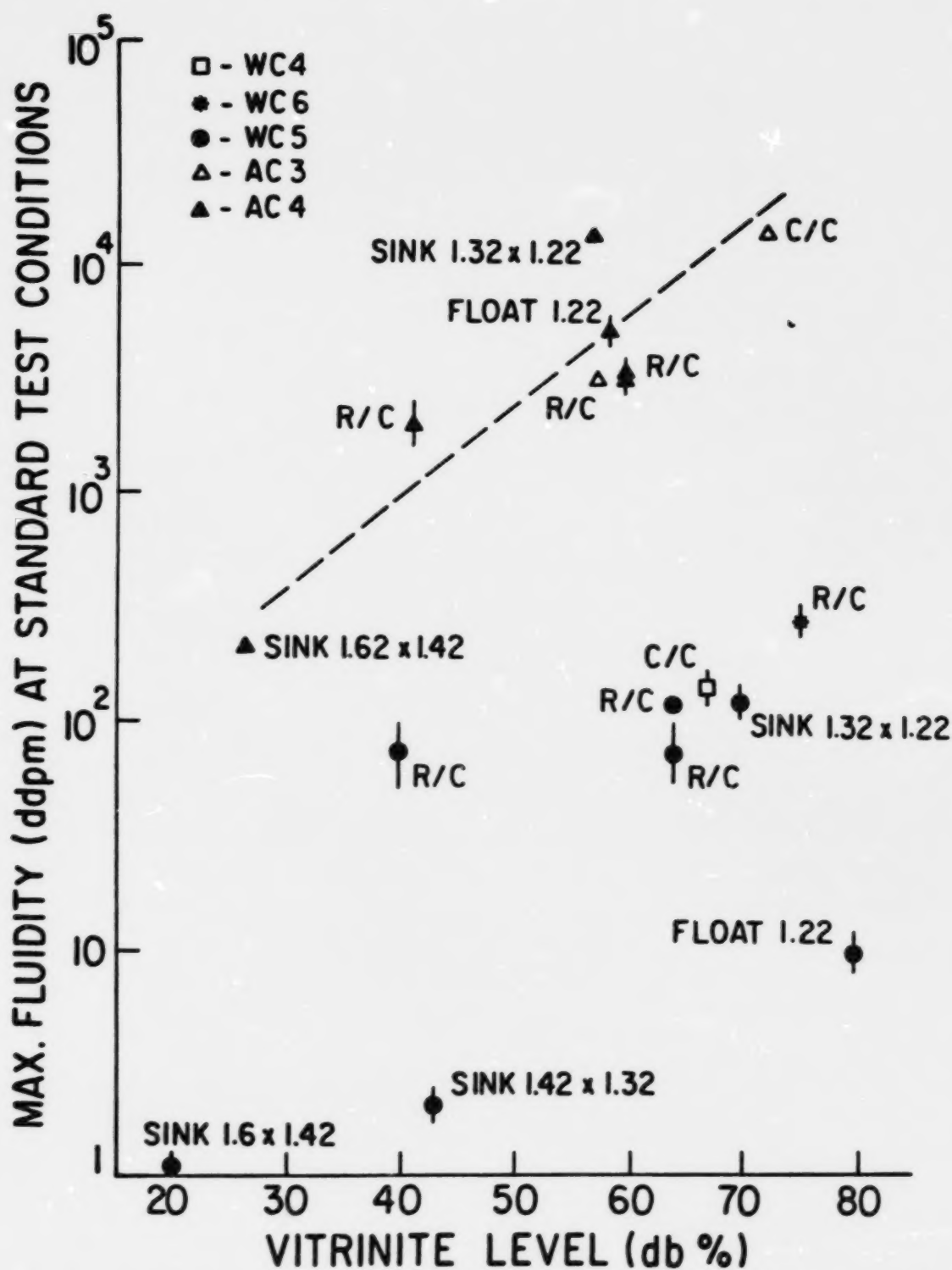


FIGURE 26 VARIATION OF MAXIMUM FLUIDITY (GIESELER) WITH VITRINITE CONTENT

DILATATION -% NON-STANDARD CONDITIONS

($[\eta]$, 3° C / min)

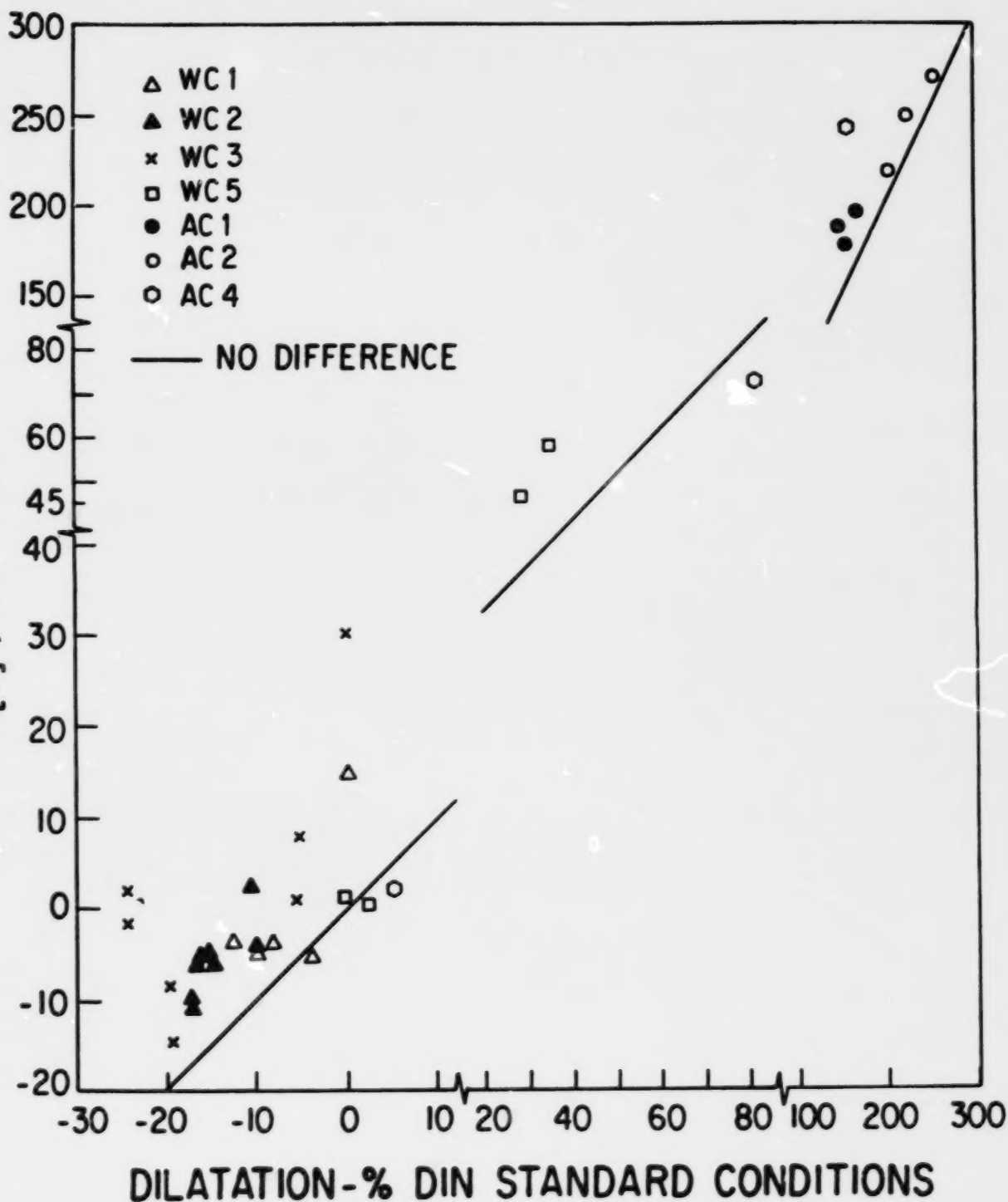


FIGURE 25 USE OF DILATATION TO ASSESS INFLUENCE OF TEST CONDITIONS ON RHEOLOGY

DILATATION -% NON-STANDARD CONDITIONS

([8] , 3° C / min)

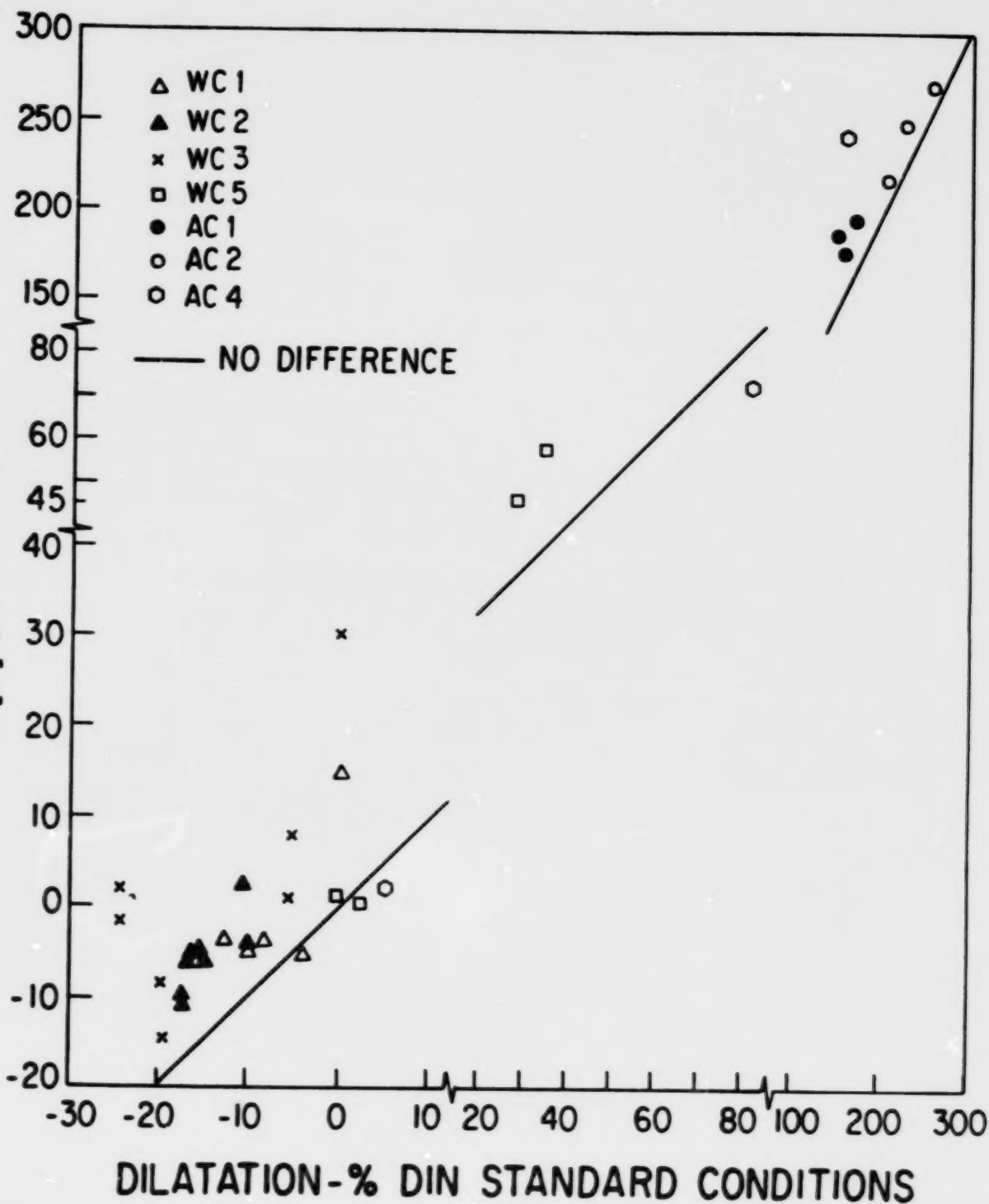


FIGURE 25 USE OF DILATATION TO ASSESS INFLUENCE OF TEST CONDITIONS ON RHEOLOGY

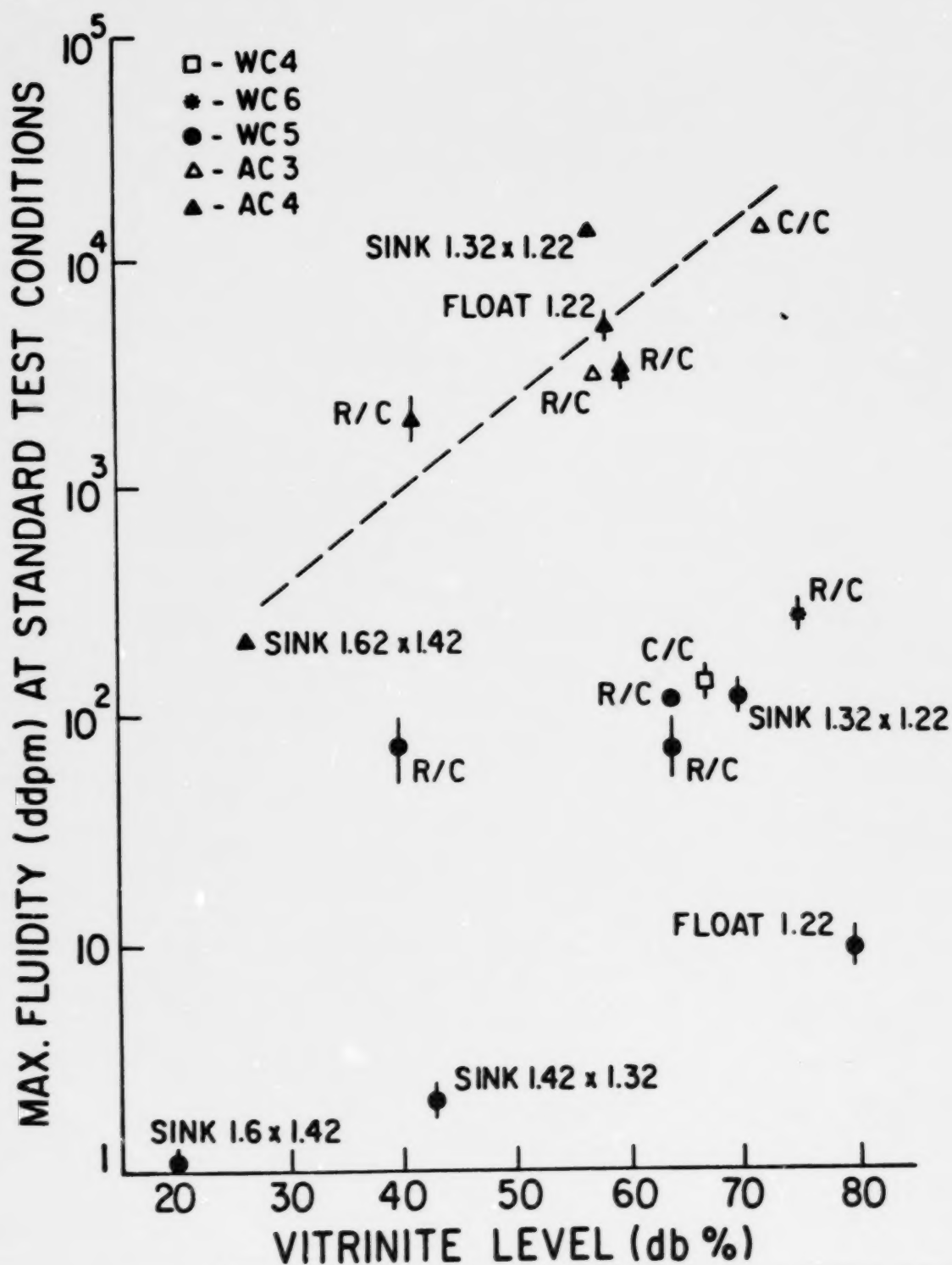


FIGURE 26 VARIATION OF MAXIMUM FLUIDITY (GIESELER) WITH VITRINITE CONTENT

for coals which have $c + d$ more than 10% under standard conditions. If the western Canadian coals have small $c + d$ or are sub plastic even an increase to [-8] mesh and 4.5°C/min. may not raise total dilatation. Figure 23 is an update of the total dilatation cross plot for the Appalachian coals. Appalachian coals used in the current study have lower total dilatations than coals examined in last year's contract. The added data show that for $c + d$ less than 120 increases in top size and heating rate may not raise total dilatation.

In the previous report the contraction and dilatation measurements were examined to see if one or both caused the increase in total dilatation. Some of this year's data is included in the reproduction of the appropriate figures from the 1983 report. Figure 24 shows the new contraction data agrees well with previous measurements. Raising top size reduces markedly % contraction of both western Canadian and Appalachian coals. On the other hand, the agreement is less apparent between the data sets for dilatation. the current data suggest top size does not increase dilatation if, under DIN standard condtions for the Ruhr instrument, the coal has little or no dilatation. Last year's data indicate a strong positive effect of top size on dilatation. At higher dilatation's under DIN standard test conditions, increasing top size can boost "d" substantially although the scale change in Figure 25 obscures the increase.

The G-factor was found in our 1983 report to be an insensitive indicator of test conditions if $G \approx 1.10$. Since even the western Canadian coals used in this contract had G-factors close to 1.10, the G-Factor cross plot for standard and non standard test conditions does not render adequately test condition changes. An updated version of a previous plot has not been included therefore.

Plastometry Results

The maximum fluidity data resemble the total dilatation data. A plot of maximum fluidity versus percent vitrinite (Figure 26) show that the western Canadian Cretaceous and Appalachian Carboniferous coals form separate

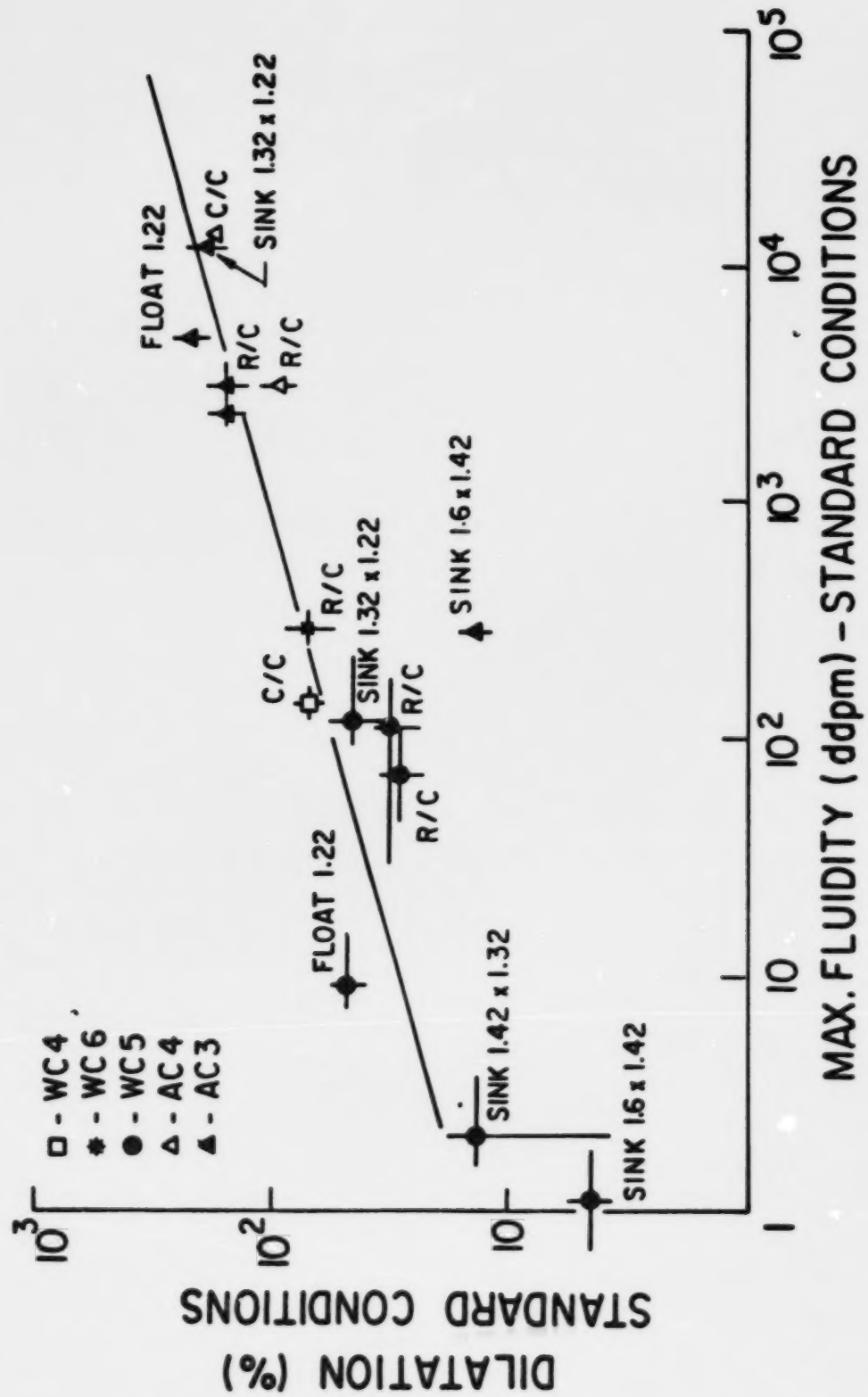


FIGURE 27 TOTAL DILATATION VS. MAXIMUM FLUIDITY UNDER STANDARD TEST CONDITIONS

populations. Maximum fluidity for the latter coals are greater than those for the western Canadian coals by almost two orders of magnitude for the same range of vitrinite content. Data for the Appalachian coals seem to define a straight line (ddpm vs vitrinite), whereas there appears to be a vitrinite content threshold for the western Canadian coals of greater than 20% for a maximum fluidity measurement. The western Canadian data scatters badly, however. A threshold was observed for total dilatation (Waterloo Centre for Process Development, 1983), but the threshold vitrinite level was 55% rather than 20%. Data from both Part I and II measurements are included in Figure 26. Vertical lines, when shown, represent the range of measurements and the symbols in these cases are the mean values. Single samples were used for petrography, however, multiple points are shown for the WC5 and AC4 raw coals. These indicate measurements made in the two parts of this work. Maximum fluidity measurements of these quite independent runs are in reasonably good agreement, especially considering one set was made with a [-35x60] mesh sample rather than the standard [-35]. Determination of the vitrinite levels differed and accounts for the spread of the data points in the figure.

Similarly of the total dilatation and maximum fluidity data is underscored in Figure 27 which cross plots the data from these two rheology procedures. With the exception of the high ash 1.6 x 1.42 sp.gr. sink samples, the remaining data points fall along a straight line. This indicates a relationship of the form:

$$(\% c + d) = K (ddpm)$$

for these two measures of rheology.

Failure of the high ash samples (sink 1.6 x 1.42 sp.gr.) to fall on the correlation may arise from measurement problems with these samples. Very low, essentially no fluidity was observed with the cretaceous coal sample (See Figures 26,27). With the carboniferous sink samples of 1.6 x 1.42 sp.gr., maximum fluidity where at or close to maximum values. It would seem this may be due to the high ash levels in these samples (40.6 and 43.0% respectively) and the nature of the ash, because this was not

Table 5
Comparison of Ruhr Dilatometer and Gieseler Plastometer Test Temperatures

COAL	DILATOMETER			PLASTOMETER		
	T_1 -Softening	T_2 -max. contr.	T_3 -max. dilat.	T_1 softening temp.	T_2 max. fluidity	T_3 solidification
WC4 (C/C) *	403	432	504	431.9	461.9	496.8
WC5 R/C	414	440	487	444.7	469.3	503.4
WC6 (R/C)	397	419	467	428.2	462.6	491.6
AC3 (R/C)	360	391	498	410.3	451.0	505.1
AC4 (R/C)	375**	399**	508	410.6	454.2	505.3

Test Conditions: Non Standard [-8] mesh; (3°C/min), all data after 3 months storage. All temperatures recorded in °C.

* average calculated from Sample 1 values

** single reading; all other values are averages

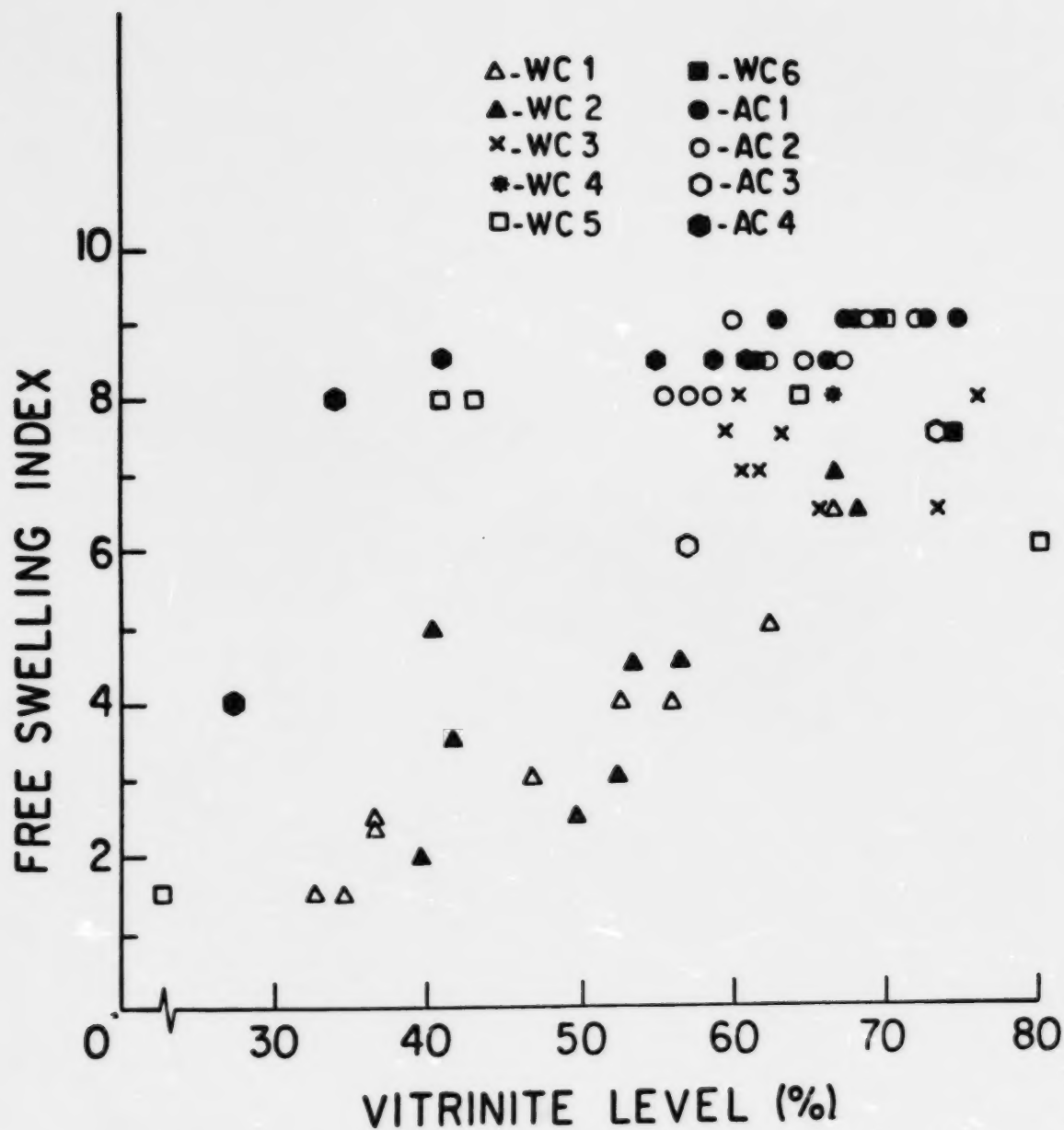


FIGURE 28 FREE SWELLING INDEX VS. VITRINITE CONTENT FOR DIFFERENT COALS STUDIED

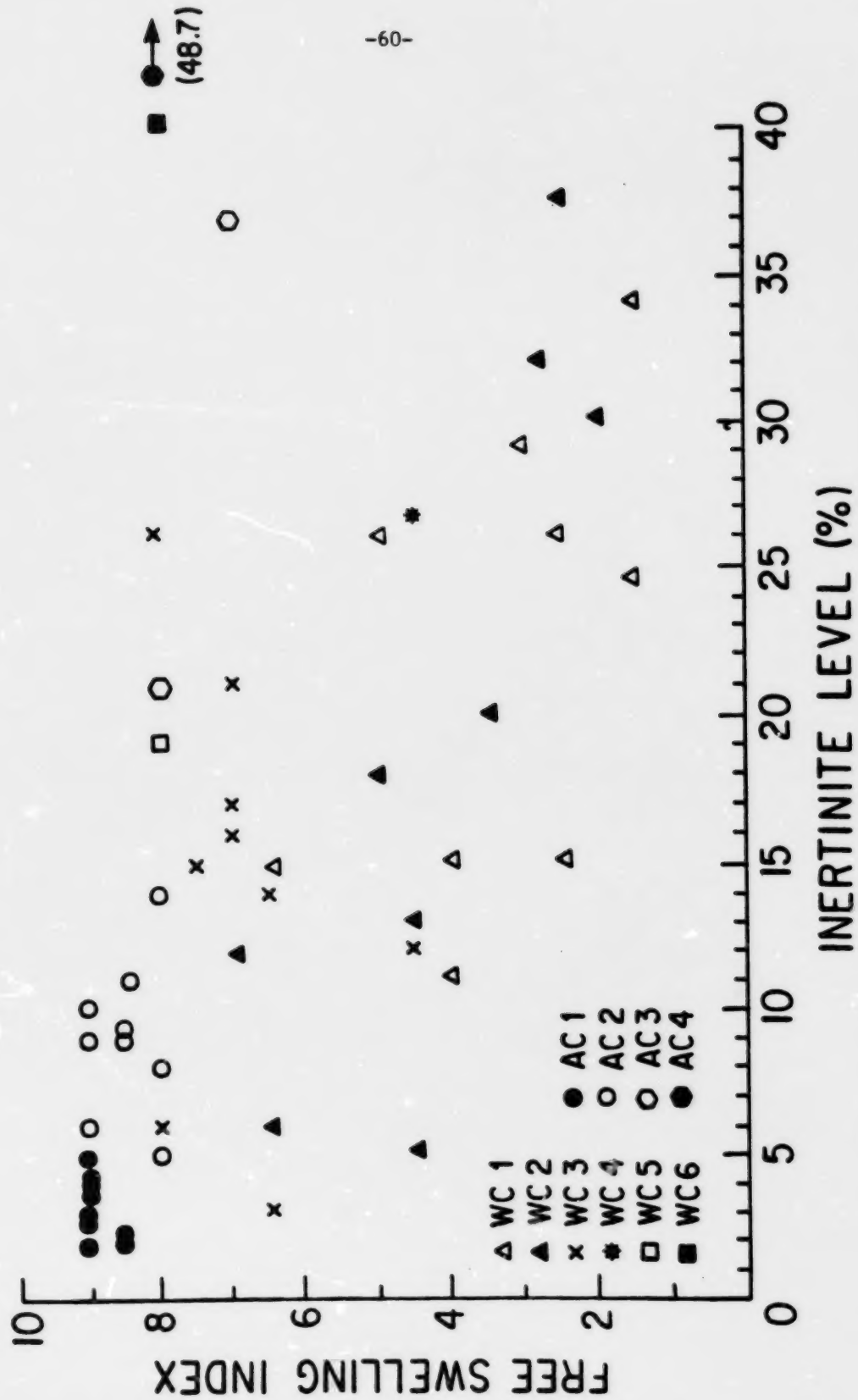


FIGURE 29 FREE SWELLING INDEX VS. INERTINITE CONTENT

seen with the cretaceous sample with a 36 percent ash content. Indeed abnormally high fluidities were never observed with the WC5 samples. On the other hand, equipment discrepancy may be the source because occasional abnormal reading (ddpm more than 20,000) were observed at a frequency of about 1 in 8 with the Appalachian coals. In the Gieseler, wild results can be obtained if the coal sample moves as an entity, like a toffee apple, in the crucible. This may also have occurred. Although these abnormal values have been retained in the data given in Appendices B and C, they are averaged or shown separately in either Figure 26 or 27.

Although softening is defined in terms of the rheological behaviour measured in each instrument, it has been assumed that they measure the same phenomena-decomposition of the original coal and the initial formation of a melt phase. The temperature of maximum dilatation is assumed to be the temperature at the melt phase disappears and a solid matrix starts to form. The plastomer measures a solidification temperature where plasticity disappears, apparently because of formation of a solid matrix. These temperatures measured in these different instruments would be expected to be close together because the same process is being observed. Table 5 compares these temperatures as well as the temperatures of maximum contraction and maximum fluidity (which do not observe the same process). It can be seen that the agreement is poor for softening but reasonably good for maximum dilatation and solidification. Indeed the differences between the two softening temperatures is about the difference between the temperatures for maximum contraction and maximum fluidity.

Free Swelling Index Results

Measurements of total dilatation and FSI in Part II confirm the observation in our previous report (Waterloo Centre for Process Development, 1983) that western Canadian and Appalachian coals of the same rank and vitrinite levels can show markedly different c + d values, but FSI ratings which differ by just 1/2 to 1 units. Figure 28 adds data from this study to a plot given in our 1983 report. The current data increase the data scatter, but do not obscure the strong relationship between FSI and vitrinite content regardless of geographical origin of the coal. Figure 29

plots FSI vs. inertinite. Because vitrinite is the overwhelming reactive in both western Canadian and Appalachian coals, inertinite correlates closely with vitrinite so that Figure 29 provides no further insight into the FSI behaviour.

It is perhaps significant that FSI measurement does not strongly segregate the western Canadian and Appalachian coals as do dilatometry and plastometry, and the test would suggest that the western Canadian coals have moderate to good coking characteristics whereas dilatometry and plastometry would indicate these coals have poor to moderate characteristics.

Comparison of Raw Coals and Float Sink Samples:

Choice of coals for Part II has been discussed earlier and the raw coals compared in Table 3. The WC5 and AC4 coals chosen for Part II had closely agreeing fixed carbon levels, almost identical vitrinite levels and reflectance. The substantial petrographic difference are the inertinite fraction where the western Canadian coal is rich in semifusinite while the Appalachian coal has high levels of micrinite. Despite these similarities, c + d and ddp_m differ substantially. Only the FSI readings are close.

Table 6 summarizes the measured properties of the individual samples generated by specific gravity separations described earlier.

Examination of the maceral and proximate analyses given in the table shows unexpected variation between the [-8x35] mesh and [-35x60] mesh source coals. Vitrinite for example, is at 79.3 percent in the [-8x35] mesh 1.22 float sample and 64.8 percent in the [-35 x60] mesh sample. Maceral analysis could not be performed on the [-60] mesh samples, so because of the [-8x35] mesh and [-35x60] mesh variation, maceral levels could not be predicted in the various sink and float fractions. The [-60] mesh samples, thus, were not used in the blend studies.

Comparing the western Canadian and Appalachian data it can be seen that vitrinite, ash, and sulfur levels for these coals overlap. Only semi

Table 6a
WCS [-8x35] mesh Fraction

Fraction	1.6x1.42	1.42x1.32	1.32x1.22	1.22	
Property	Sink	Sink	Sink	Float	Raw
Maceral Analysis					
Vitrinite	20.2	42.9	69.5	79.3	63.6
Exinite	-	1.9	0.2	-	-
Semi-fusinite	44.9	39.9	22.1	12.8	21.9
Fusinite	9.6	6.1	0.8	1.8	4.0
Micrinite	1.8	4.6	4.5	4.1	5.7
Mineral Matter	23.5	4.6	2.9	2.0	4.8
Vitrinite/Semi-fusinite	0.450	1.08	3.14	6.20	2.90
Vitrinite/F+SF	0.370	0.933	3.03	5.43	2.46
Total Reactives	42.6	64.8	80.7	85.7	74.5
Reflectance					
Random R	1.06	1.05	1.05	1.06	1.08
Maximum R ₀	1.12	1.11	1.11	1.12	1.14
Proximate/Ulimate Analysis					
Fixed Carbon (daf)					74.6
Ash (db)	36.3	8.2	4.4	3.7	8.4
S (db)	0.51	0.5	1.1	0.2	0.75
Sieve Analysis					
-8 wt%					38.4
-10 wt%					35.1
-18 wt%					8.0
-20 wt%					11.8
-28 wt%					4.2
-32 wt%					2.5
Rheology (Standard Test Conditions)					
c+d %	2.4	8.3	6.0	55	23
Maximum Fluidity ddpm	-	-	4.7	17.4	45.3
FSI	1½	7½	9	6	

Table 6b
WCS [-35x-60] mesh Fraction

Fraction	1.6x1.42	1.42x1.32	1.32x1.22	1.22	
Property	Sink	Sink	Sink	Float	Raw
Maceral Analysis					
Vitrinite	34.0	44.0	56.9	64.8	50.0
Exinite	-	0.7	1.6	0.4	0.4
Semi-fusinite	37.9	35.7	22.8	19.7	29.1
Fusinite	10.2	4.6	10.7	4.8	12.0
Micrinite	2.9	7.0	5.5	5.9	1.8
Mineral Matter	15.0	8.0	2.5	4.4	6.7
Vitrinite/Semi-fusinite	0.897	1.23	2.50	3.29	1.72
Vitrinite/F+SF	0.707	1.09	1.70	2.64	1.22
Total Reactives	52.9	62.5	69.9	75.0	65.0
Reflectance					
Random R	1.06	1.05	1.05	1.06	
Maximum R _o	1.12	1.11	1.11	1.12	
Proximate/Ultime Analysis					
Fixed Carbon (daf)					
Ash (db)	24.4	13.6	4.2	7.9	12.0
S (db)	0.51	0.50	1.1	0.21	0.21
Rheology (Standard Test Conditions)					
c+d %	6.3	10.8	54.5	41	48.9
Maximum Fluidity ddm	1.1	2.1	118	9.2	113.5
FSI	1½	2½	8	7½	6½

Table 6c
WC5 [-60] mesh Fraction

Fraction	1.6x1.42	1.42x1.32	1.32x1.22	1.22	
Property	Sink	Sink	Sink	Float	Raw
Maceral Analysis					
Vitrinite					
Exinite					
Semi-fusinite					
Fusinite					
Micrinite					
Mineral Matter					
Vitrinite/Semi-fusinite					
Vitrinite/F+SF					
Total Reactives					
Reflectance					
Random R					
Maximum R_o					
Proximate/Ultime Analysis					
Fixed Carbon (daf)	73.1	75.3	74.7	75.5	74.6
Ash (db)	36.3	8.2	4.4	3.7	8.4
S (db)					
Sieve Analysis					
-60 wt%		21.5	88.2	77.4	97.1
-100 wt%		69.4	10.0	16.0	1.4
-170 wt%		8.2	1.4	5.5	1.3
-270		1.0	0.4	1.1	0.2
Rheology (Standard Test Conditions)					
c+d %	4.5	13.6	46.1	48.4	35.4
Maximum Fluidity ddmh	1.0	1.7	70.3	9.3	45.6
FSI	1½	8	9	6	8

Table 6d
AC4 [-8x35] mesh Fraction

Property	Fraction 1.6x1.42 Sink	1.42x1.32 Sink	1.32x1.22 Sink	1.22 Float	Raw
Maceral Analysis					
Vitrinite	26.3	32.7	56.8	58.0	59.5
Exinite	5.6	6.5	2.7	5.8	2.9
Semi-fusinite	27.2	16.6	12.3	12.5	11.9
Fusinite	5.0	3.8	2.7	3.4	2.8
Micrinite	8.3	11.2	19.9	15.4	13.8
Mineral Matter	27.6	29.2	5.6	4.9	9.0
Vitrinite/Semi-fusinite	0.967	1.97	4.62	4.64	5.0
Vitrinite/F+SF	0.817	1.60	3.79	3.65	4.05
Total Reactives	41.0	44.7	63.6	68.0	66.5
Reflectance					
Random R	1.05	1.05	1.05	1.06	1.06
Maximum R _o	1.11	1.11	1.11	1.12	1.12
Proximate/Ultimate Analysis					
Fixed Carbon (daf)					69.7
Ash (db)	40.6	43.0	9.6	8.5	15.5
S (db)	1.7	1.0	0.82	0.9	1.0
Sieve Analysis					
- 8 wt%					25.9
-10 wt%					37.3
-18 wt%					10.5
-20 wt%					14.6
-28 wt%					6.2
-32 wt%					5.5
Rheology (Standard Test Conditions)					
c+d %	6.2	82.2	257	239	193
Maximum Fluidity ddbb malfunction		15900	6800	4300	8100
FSI	1	7½	8½	8½	

Table 6e
AC4 [-35x60] mesh Fraction

Property	Fraction 1.6x1.42 Sink	1.42x1.32 Sink	1.32x1.22 Sink	1.22 Float	Raw
Maceral Analysis					
Vitrinite	35.1	40.3	59.5	62.3	
Exinite	2.0	3.6	2.8	1.6	
Semi-fusinite	27.1	20.4	20.0	13.8	
Fusinite	5.1	5.7	4.2	7.2	
Micrinite	5.7	11.0	9.4	12.2	
Mineral Matter	25.0	19.0	4.1	2.9	
Vitrinite/Semi-fusinite	1.30	1.98	2.98	4.51	
Vitrinite/F+SF	1.09	1.54	2.46	2.97	
Total Reactives	46.1	50.7	68.9	68.5	
Reflectance					
Random R	1.05	1.05	1.05	1.06	
Maximum R _o	1.11	1.11	1.11	1.11	
Proximate/Ultime Analysis					
Fixed Carbon (daf)					
Ash (db)	37.0	30.4	7.8	5.4	
S (db)	1.7	1.0	0.82	0.89	
Sieve Analysis					
-60 wt%					
-100 wt%					
-170 wt%					
-270 wt%					
Rheology (Standard Test Conditions)					
c+d %	10	51.7	183	205	211
Maximum Fluidity ddmb	310	malfunction	1200	4830	3050
FSI	1	4½	8½	9	4½

Table 6f
AC4 [-60] mesh Fraction

Fraction	1.6x1.42	1.42x1.32	1.32x1.22	1.22	
Property	Sink	Sink	Sink	Float	Raw
Maceral Analysis					
Vitrinite					
Exinite					
Semi-fusinite					
Fusinite					
Micrinite					
Mineral Matter		NO DATA			
Vitrinite/Semi-fusinite					
Vitrinite/F+SF					
Total Reactives					
Reflectance					
Random R		NO DATA			
Maximum R_o					
Proximate/Ultime Analysis					
Fixed Carbon (daf)	67.1	59.9	71.1	72.3	71.7
Ash (db)	40.6	43.0	9.6	8.5	17.9
S (db)					
Sieve Analysis					
-60 wt%		42.4	72.7	69.7	94.5
-100 wt%		3.4	22.9	25.7	5.1
-170 wt%		50.0	3.8	4.0	0.3
-270		4.2	0.6	0.6	0.1
Rheology (Standard Test Conditions)					
c+d %	13.6	105	197	219	168
Maximum Fluidity ddbb malfunction		malfunction	7160	malfunction	3300
FSI	4	8	8½	8½	8½

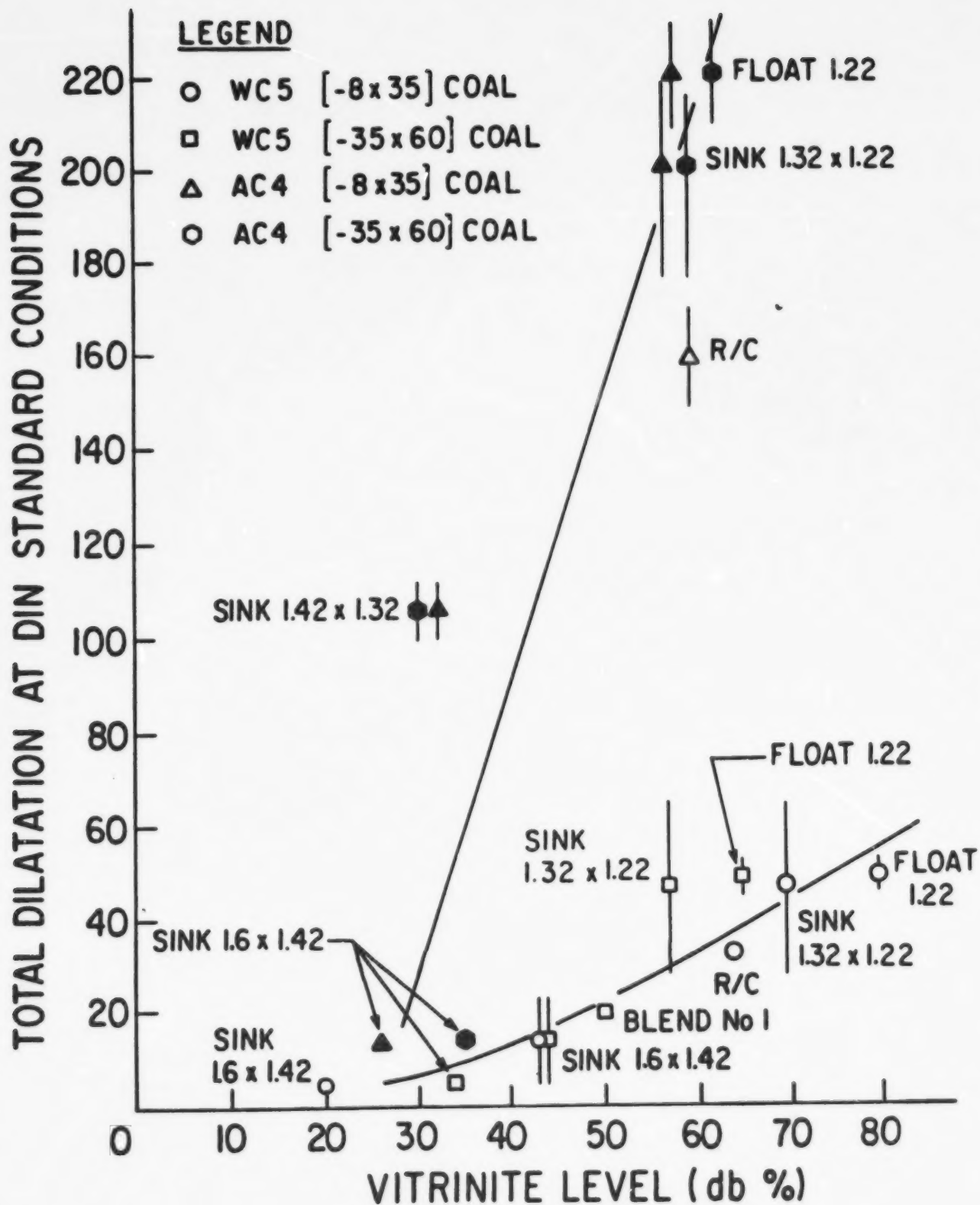


FIGURE 30 COMPARISON OF TOTAL DILATATION FOR THE WC5 AND AC4 COALS

fusinate, micrinite and to a lesser extent total reactives fall in separate ranges. Because vitrinite reflectances are also quite similar, rheological measurements would be expected to be of the same magnitude at least. Figure 30, plotting total dilatation (DIN Standard conditions) versus vitrinite, shows total dilatations are close in magnitude in the low vitrinite samples (high specific gravity sink samples), but diverge sharply at higher vitrinite levels. Consequently, the inert components seem to be important in dilatometry Cretaceous and Carboniferous vitrinites of the same reflectance soften, expand and resolidify differently.

Curiously, the FSI data for the WC and AC coals (see figure 29) overlap in the range of vitrinite levels covered with the WC5 and AC4 coals. Scatter, however, is a problem with this data. Both Table 6 and Figure 28 indicate FSI goes through a maximum as reactives and fixed carbon (daf) increase. The plastometry data for the AC coal is unreliable so a comparison with western Canadian coal values cannot be made.

Blend Results:

These experiments were designed to investigate the source of the rheology differences illustrated in Figure 30. Originally, the intent of the experiment was with just one blend to match the variables earlier experiments had indicated to be important. The measurements on blend #1 persisted in showing a substantial dilatometry difference despite matching so the blending experiments were augmented to examine reactive inert ratio and total inerts. Even though the experiments were performed sequentially building on results obtained with the previous blend, we discuss the experiments as though they were performed together.

Blends 1 and 2 tested close matching of vitrinite content, ash and particle size distribution on rheology. Particle size distribution was handled by weighting each sieve cut with a coefficient. These summed to 1.0 which was the weighting used on vitrinite and ash. Particle size weighting were varied down to zero (taking this variable out of the match) with just a small change in the fractions of the two coals chosen. Apparently, size distributions were sufficiently alike in each float sink

Table 7a
Blend #1 - Vitrinite + Ash Matched

Property	Target	Blend Samples		Predicted	Measured
	Coal AC4 [-8x35]	WC5 [-8x35] 1.6x1.42 Sink	WC5 [-8x35] 1.22 Float	Properties Blend	Properties Blend
Maceral Analysis					
Vitrinite	*59.5	x 0.322 20.2	x 0.678 79.3	60.3	50.0
Exinite	2.9	-	-	-	4.0
Semi-fusinite	11.9	44.9	12.8	23.1	29.1
Fusinite	2.8	9.6	1.8	4.3	12.0
Micrinite	13.8	1.8	4.1	3.4	1.8
Mineral Matter	9.0	23.5	2.0	8.9	6.7
V/SF	5.0	0.45	6.20	2.61	1.72
V/(F + SF)	4.05	0.37	5.43	2.20	1.22
Total Reactives	66.5	42.6	85.7	71.9	68.6
Total Inerts	33.5			28.1	31.4
Microlithotype Analysis					
Liptite	-			-	
Clarite	2			-	
Vitrite	32			56.82	
Vitrinertite	24			21.83	
Inertite	30			20.04	
Trimacerite	11			1.32	
Durite	1			-	
Proximate/Ultime Analysis					
Fixed Carbon (daf)	69.7				
Ash (db)	*15.5	36.3	3.7	13.8	11.1
S (db)	1.0	0.51	0.20	0.29	
Rheology (Standard Test Conditions)					
c+d %	193	2.4	55		112
Maximum					
Fluidity ddpm	8100		17.4		740
FSI					5

Table 7b
Blend #2 - Vitrinite, Ash and Sulfur Matched

Property	Target	Blend Samples		Predicted	Measured
	Coal WC5 [-8x35] R/C	AC4 [-8x35] 1.22 Float		Properties Blend	Properties Blend
Maceral Analysis					
Vitrinite	*63.6	1.00			58.0
Exinite	-	58.0			5.8
Semi-fusinite	21.9	5.8			12.5
Fusinite	4.0	12.5			3.4
Micrinite	5.7	3.4			15.4
Mineral Matter	4.8	15.4			4.5
V/SF	2.90	4.9			4.64
V/(F + SF)	2.46	4.64			3.65
Total Reactives	74.5	3.65			68.0
Total Inerts		68.0			32.0
		32.0			
Microlithotype Analysis					
Liptite	-	-			
Clarite	-	1			
Vitrite	35	72			
Vitrinerite	29	10			
Inertite	28	15			
Trimacerite	8	2			
Durite	-	-			
Proximate/Ulimate Analysis					
Fixed Carbon (daf)	74.6				
Ash (db)	*8.35	8.5			8.5
S (db)	*0.75	0.9			0.9
Rheology (Standard Test Conditions)					
c+d %	23	239			239
Maximum					
Fluidity ddpm	45.1	4300			4300
FSI		8½			8½

Table 7c
Blend #3 - Vitrinite, Ash and Vitrinite/Fusinite Ratio Matched

Property	Target	Blend Samples				Predicted	Measured
	Coal					Properties	Properties
	AC4 [-8x35] 1.22 Float	WC5 [-8x35] 1.6x1.42 Sink	WC5 [-8x35] 1.4x1.32 Sink	WC5 [-8x35] 1.22 Float	Blend	Blend	Blend
Maceral Analysis		0.128	0.349	0.521			
Vitrinite	*58.0	20.2	42.9	79.3	58.9		
Exinite	5.8	-	1.9	-	0.7		
Semi-fusinite	12.5	44.9	39.9	12.8	26.3		
Fusinite	3.4	9.6	6.1	1.8	4.3		
Micrinite	15.4	1.8	4.6	4.1	4.0		
Mineral Matter	4.9	23.5	4.6	2.0	5.7		
V/SF	4.64	0.45	1.08	6.2	2.24		
V/(F + SF)	*3.65	0.37	0.93	5.43	1.92 #		
Total Reactives	68.0	42.6	64.8	85.7	72.7		
Total Inerts	32.0	57.4	35.2	14.3	27.3		
Microlithotype							
Liptite	-				-		
Clarite	1				0.3		
Vitrite	72				50.4		
Vitrinertite	10				26.6		
Inertite	15				17.9		
Trimacerite	2				4.6		
Durite	-				-		
Proximate/Ultime Analysis							
Fixed Carbon (daf)							
Ash (db)	*8.5	36.3	8.2	3.7	9.4	12.7	
S (db)	0.9	0.51	0.50	0.2	.34		
Rheology (Standard Test Conditions)							
c+d %	239	2.4	8.3	55		8.6	
Maximum							
Fluidity ddpm	4300			17.4			
FSI	8½	1½	7½	6		4½	

Error in program set up: target V/F+SF set up at 2.5

Table 7d
Blend #4 - Vitrinite, Ash and Vitrinite/Semi-fusinite Ratio Matched

Property	Target	Blend Samples		Predicted	Measured
	Coal WC5 [-35x60] 1.22 Float	AC4 [-35x60] 1.6x1.42 Sink	AC5 [-35x60] 1.22 Float	Properties Blend	Properties Blend
Maceral Analysis		0.041	0.958		
Vitrinite	*64.8	35.1	62.3	61.1	
Exinite	0.4	2.0	1.6	1.6	
Semi-fusinite	19.7	27.1	13.8	14.3	
Fusinite	4.8	5.1	7.2	7.1	
Micrinite	5.9	5.7	12.2	11.9	
Mineral Matter	4.4	25.0	2.9	3.0	
V/SF	*3.29	1.30	4.51	4.3	
V/(F + SF)	2.64	1.09	2.57	2.9	
Total Reactives	75.0	46.1	68.5	69.8	
Total Inerts	25.0	53.9	31.5	30.2	
Proximate/Ultime Analysis					
Fixed Carbon (daf)					
Ash (db)	*7.9	37.0	5.4	6.7	6.2
S (db)	0.21	1.7	0.89	1.0	
Rheology (Standard Test Conditions)					
c+d %	41	10	205		217
Maximum					
Fluidity ddpm	9.2	310	4830		
FSI	7½	1	9		8

Table 7e
Blend #5 - Vitrinite, Ash and Vitrinite/Fusinite Ratio Matched

Property	Target	Blend Samples		Predicted	Measured
	Coal			Properties	Properties
	AC5 [-35x60] 1.22 Float	WC4 [-35x60] 1.32x1.22 Sink	WC5 [-35x60] 1.22 Float	Blend	Blend
Maceral Analysis		0.358	0.641		
Vitrinite	*62.3	56.9	64.8	61.9	
Exinite	1.6	1.6	0.4	0.8	
Semi-fusinite	13.8	22.8	19.7	20.7	
Fusinite	7.2	10.7	4.8	6.9	
Micrinite	12.2	5.5	5.9	5.8	
Mineral Matter	2.9	2.5	4.4	3.7	
V/SF	4.51	2.50	3.29	2.99	
V/(F + SF)	*2.97	1.70	2.64	2.24	
Total Reactives	68.5	69.9	75.0	73.0	
Total Inerts	31.5	30.1	25.0	27.0	
Proximate/Ultime Analysis					
Fixed Carbon (daf)					
Ash (db)	*5.4	4.2	7.9	6.6	4.8
S (db)	0.89	1.1	0.21	0.53	
Rheology (Standard Test Conditions)					
c+d %	205	54.5	41		47
Maximum					
Fluidity ddpm	4830	118	9.2		
FSI	9	8	7½		8½

Table 7f

Property	Target	Blend Samples				Predicted	Measured
	Coal				Properties	Properties	
	AC4 [-35x60] 1.32x.122 Sink	WC5 [-35x60] 1.6x1.42 Sink	WC5 [-35x60] 1.32x1.22 Sink	WC5 [-35x60] 1.22 Float	Blend	Blend	
Maceral Analysis		0.051	0.249	0.699			
Vitrinite	59.5	34.0	56.9	64.8	61.2		
Exinite	2.8	-	1.6	0.4	0.7		
Semi-fusinite	20.0	37.9	22.8	19.7	21.4		
Fusinite	4.2	10.2	10.7	4.8	6.5		
Micrinite	9.4	2.9	5.5	5.9	5.6		
Mineral Matter	4.1	15.0	2.5	4.4	4.5		
V/SF	2.98	0.90	2.50	3.29	2.85		
V/(F + SF)	2.46	0.71	1.70	2.64	2.19		
Total Reactives	68.9	52.9	69.9	75.0	72.6		
Total Inerts	31.1	47.1	30.1	25.0	27.4		
Proximate/Ultime Analysis							
Fixed Carbon (daf)							
Ash (db)	*7.8	24.4	4.2	7.9	7.8	6.1	
S (db)	0.82	0.51	1.1	0.21	0.45		
Rheology (Standard Test Conditions)							
c+d %	183	6.3	54.5	41		35	
Maximum							
Fluidity ddpm	1200	1.1	118	9.2			
FSI	8½	1½	8	7½		7	

Table 7g
Blend #7 - Inertinite and Ash Matched

Property	Target	Blend Samples		Predicted	Measured
	Coal			Properties	Properties
	WC5 [-35x60] 1.22 Float	AC4 [-35x60] 1.42x1.32 sink	AC4 [-35x60] 1.22 Float	Blend	Blend
Maceral Analysis		0.038	0.969		
Vitrinite	64.8	40.3	62.3	61.9	
Exinite	0.4	3.6	1.6	1.7	
Semi-fusinite	19.7	20.4	13.8	14.1	
Fusinite	4.8	5.7	7.2	7.2	
Micrinite	5.9	11.0	12.2	12.2	
Mineral Matter	4.4	19.0	2.9	3.5	
V/SF	3.29	1.98	4.51	4.39	
V/(F + SF)	2.64	1.54	2.97	2.91	
Total Reactives	75.0	50.7	68.5	70.6	
Total Inerts	25.0	49.3	31.5	29.4	
Proximate/Ultime Analysis					
Fixed Carbon (daf)					
Ash (db)	*7.9	30.4	5.4	6.4	9.1
S (db)	0.21	1.0	0.89	0.90	
Rheology (Standard Test Conditions)					
c+d %	41	51.7	205		192
Maximum					
Fluidity ddpm	9.2		4830		
FSI	7½	4½	9		8

Table 7h
Microlithotypes Matched

[-8 x 35] mesh

Float-Sink Fraction	1.32 x 1.22		+ 1.22	
Coal	WC5	AC4	WC5	AC4
Microlithotype, %				
Liptite	-	-	-	-
Clarite	-	2	-	1
Vitrite	43	38	80	72
Vitrinite	41	43	17	10
Inertite	12	14	2	15
Trimacerite	4	3	1	2
Durite	-	-	-	-
Maceral Analysis, %				
Vitrinite	69.5	56.8	79.3	58.0
Exinite	0.2	2.7	-	5.8
Semi-Fusinite	22.1	12.3	12.8	12.5
Fusinite	0.8	2.7	1.8	3.4
Micrinite	4.5	19.9	4.1	15.4
Mineral Matter	2.9	5.6	2.0	4.9
V/SF				
V/F+SF				
Total Reactives	80.7	65.7	85.7	70.1
Total Inerts	19.3	34.3	14.3	29.9
c + d (DIN)	60	256	55	239
c + d @ 4.5°C/min	81	278	68	279
FSI	9	8½	6	8½

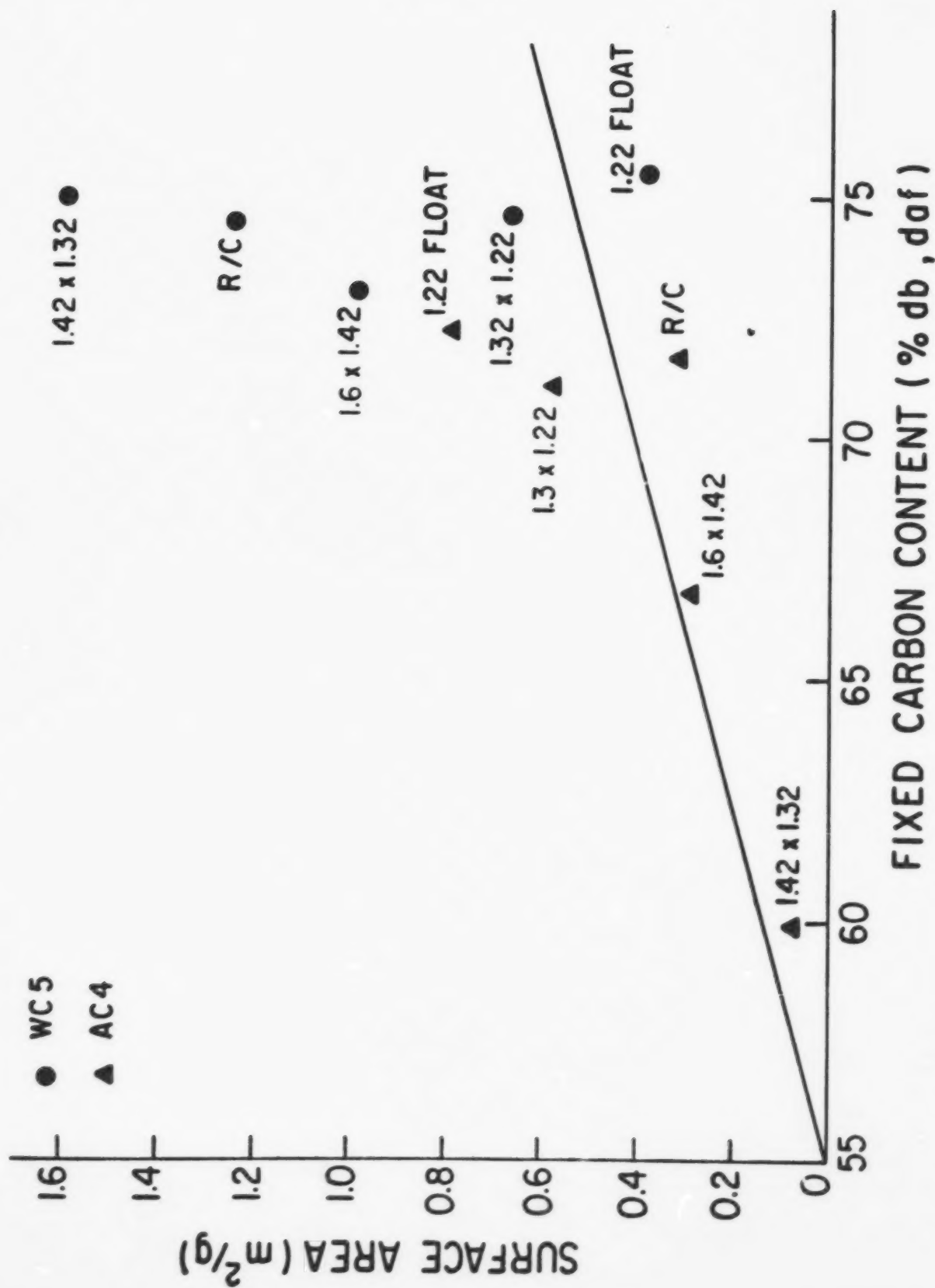


FIGURE 31 VARIATION OF N_2 SURFACE AREA OF FLOAT-SINK SAMPLES

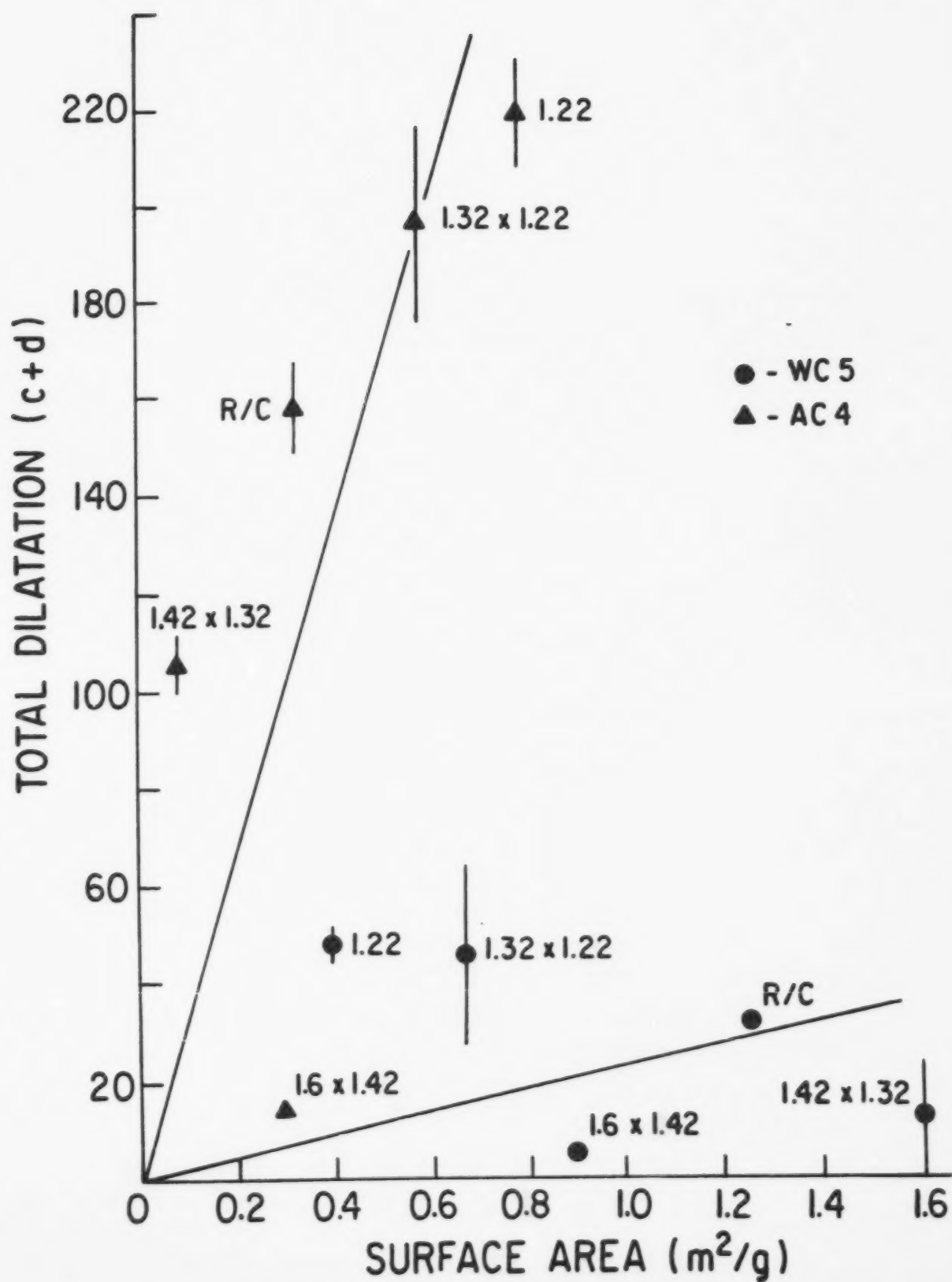


FIGURE 32 VARIATION OF TOTAL DILATATION WITH N_2 SURFACE AREA OF FLOAT SINK SAMPLES

fraction that this variable could not be adequately explored in the blend experiments. It was dropped in blend #2 and sulfur was substituted instead. This change distorted the symmetry of blend #1 and #2 which used a Carboniferous and Cretaceous (R/C) coals (respectively) as targets and blended the other coal to meet the target coal characteristics. Results are indicated in Tables 7a and 7b. Blending the western Canadian coals to match the Appalachian coals raised the total dilation to 112 percent, much higher than any of the blend components, but still only about 60 percent of the total dilatation of the Appalachian target coal. In the reverse experiment, the blending program chose a single Appalachian coal, a float, as the best match. Its total dilatation was 10 times the target total dilatation. Comparison of the vitrinite levels show that in blend #1 the western Canadian level was low, while in #2 the Appalachian level was low. This suggests that the mismatch was not sufficient to account for the 1/2 and 10x dilatometry difference. A similar argument can be made for the mismatch in ash level. It is interesting for blend #2 in Table 7b that the FSI measurements agree exactly.

In blend #1, petrography and ash content was measured to test the procedure. Results shown in Table 7a are disappointing. Vitrinite levels are about 17 percent off, and the minor macerals, excinite, fusinite and micrinite very seriously in error. Ash weight percent was about 25% off. Probably accumulated small errors in the blend components, each with widely varying maceral compositions and ash levels is responsible for the relatively unsatisfactory composition prediction. Unfortunately, time did not permit further tests of maceral composition prediction. Ash levels were routinely tested, however, and prediction errors ranged between 20 and 35 percent.

Blends #3, #4 and #5 chose coals to match the ratio of vitrinite to semi-fusinite or to both semi-fusinite and fusinite. The choice of the ratio was not too important because fusinite and semi-fusinite change on cleaning in the same way. Vitrinite levels and ash content was also matched. Unity weighting factors were used for each characteristic. Unfortunately, an error in the computer input caused a poor match of the vitrinite/total fusinite ratio. Nonetheless, a close match was obtained on

the vitrinite level. Table 7c shows that despite this close match total dilatation of the blend was 8.6, more than an order of magnitude below the $c + d$ of the target coal. Even the FSI of the target coal was not approached.

For the remaining blends in the set, the first, blend #4, used Appalachian coals and had a maceral composition slightly less in vitrinite and semi-fusinite, but substantially higher in fusinite and micrinite. The vitrinite/semi-fusinite ratio was high, but the ash level was low. Blend #5 used western Canadian coals and showed a close match of vitrinite and ash. Nonetheless, the semi-fusinite level in the blend was higher than in the target coal while the micrinite level was much lower. The vitrinite total-fusinite ratio was about 25% lower than the target. It can be seen from Table 7d and 7e that the total dilatation of the blends fails badly to match the total dilatation of the target. The FSI measurement agree very well on the other hand, even though the blend components FSI are very different.

The last set of blends match the inertite levels and the ash content. Tables 7f and 7g provide the data. It can be seen from these tables that this blending strategy provided close matches not only of the inertities and ash, but also of the maceral analyses. The target and blend match quite well (except for micrinite) for blend #6. The match is generally poorer for blend #7. Even though the characteristics of the Cretaceous and Carboniferous coals are about as alike as possible, the total dilatation of the blends failed badly, by a factor of 5, to match the total dilatation of the target coals. Once again, FSI agreement of blend #7 is very good while the agreement in blend #6 is just beyond the region of uncertainty for this type of measurement

Micro lithotype analysis requires coal particles of reasonable size to enable five points of intersection on a single coal particle. Hence, it was deemed impractical (and probably misleading) to do micro lithotype analysis of coal fractions < 35 mesh. In any event, micro lithotype analysis of a significant number of samples were done. The data are to be found in Tables A8 and C7. Surprisingly, the micro lithotype analysis of

the western Canadian and Appalachian coals are similar and shed no light on the significantly different rheology demonstrated by the two coal types (Table A8).

The analysis of the float-sink [8x35] mesh fraction show greater variation (Table C7) but again no distinct pattern to rheological properties is apparent. In fact, the closest microlithotype matches are to be found in the 1.32 x 1.22 and 1.22 float-sink fractions. As shown in Table 7h, good correspondence in microlithotype does not lead to good correspondence in demonstrated rheological properties.

Surface Area

This property is not normally associated with coking coals. Surface areas, however, related significantly to gasification and it was introduced in this study because it appears from our previous work (Waterloo Centre for Process Development, 1983) that a possible swelling process in the Cretaceous coals involves bridging between coal maceral fragments. Thus, surface area could be a factor explaining the rheology differences that are the subject of this contract. Although coal surface area is notoriously difficult to measure because of the narrow neck (ink bottle) structure of coal micropores, if consistent procedures are used, results useful for gasification can be obtained. In general, measurements shows that the accessible surface area decrease with fixed carbon reaching a minimum in the semi-anthracite rank of about 89 percent (wt.daf.).

Data collected in Part II showing variation of surface area with fixed carbon are plotted in Figure 31. Surface areas are low, but within the usual range of $0.01 \text{ m}^2/\text{g}$ to $10 \text{ m}^2/\text{g}$. Unlike the usual literature data, surface area increases with fixed carbon. Surface areas overlap for the coals so it is not surprising that total dilatation versus surface area gives separate curves for the western Canadian and Appalachian coals. This is illustrated for the WC5 and AC4 coals by Figure 32.

INTERPRETATION

In our previous contract (Waterloo Centre for Process Development, 1983) and earlier work under a research grant (Ramachandran, 1984) we found that western Canadian and Appalachian coking coals of equal rank gave greatly different dilatometry results even when the dilatometric test conditions were substantially varied to increase both the contraction and dilatation of the western Canadian coals. Based on these observations, we adapted Mackowsky's conjecture that dilatation of coals during the coking transformation result from simultaneous formation of expanding gas bubbles in the plastic stage and bridging between adjacent maceral fragments or particles which entrap expanding gas (from devolatilization). We hypothesized that the markedly different inertite compositions of the western Canadian and Appalachian coals makes the interparticle bridging process predominate or least become more important in the western Canadian coals. The blending experiments discussed in the previous section permit a test of this hypothesis even though perfect matches of the western Canadian and Appalachian coals were not achieved. The surface area measurements are useful because if the bridging mechanism is important, dilatation should be raised by higher surface area. Differences were found even with equal surface area. The hypothesis was that bridging would predominate in the western Canadian coals. This is now doubtful. Equal inertite levels in the coals and a good match in the semifusinite in particular did not result in roughly like dilatation. However, the differences which were greater than an order of magnitude for coals of equal rank in our previous study dropped to factors of 5. Inertite composition, therefore, cannot be the major source of the dilatometry differences.

Differences in blends with nearly equal vitrinite levels and vitrinite reflectance imply that this mineral, which looks the same under the microscope, differs in composition and behaves differently on melting and devolatilization. This goes against the investigations of Dutch researchers (Van Krevelan, 1970) who indicate vitrinites of the same rank will provide the same dilatation. Vitrinites of different rank, however, have different dilatations.

The influence of ash could be the source of the difference as well using the blend experiments. To discount this, we rely on the wealth of literature data (Van Krevelen, 1970) which ties melting and devolatilization in coking to vitrinite and exinite.

Exinite may also contribute to the western Canadian and Appalachian dilatometric differences. Exinites are thought to act as plasticizers for the decomposing vitrinites and large differences existed between the western Canadian and Appalachian samples, even in the blending experiments. Unfortunately, time did not permit a test of the exinite influence.

Other differences beside exinite and the inertite composition which may contribute to dilatometry differences are the more rapid loss of dilatation with time (aging) exhibited by the western Canadian coals and a slight tendency to form finer particles on crushing and grinding.

Dilatometry differences between western Canadian cretaceous and Appalachian carboniferous coals remain, it seems, even when differences in rank, ash, maceral composition and reflectance are eliminated. The question is what is to be done to make rheology a useful tool for predicting coke properties of western Canadian coals and for blending western Canadian coals among themselves or with other coals.

Two approaches seem possible. The first is to continue to use Ruhr dilatometers or Gieseler plastometers but change the test conditions by raising top size and heating rate so reasonably large values of dilatation or maximum fluidity may be obtained. A new set of strength-stability relations for the western Canadian coals and for their blends would have to be devised to accompany the revised test conditions.

The second approach is to recognize the weakness of both plastometry and dilatometry because they give quite different correlations for the otherwise like coals, and develop a difference rheological device. The logical direction for a device to follow is the system used for the Free Swelling Index. As shown in the previous section, FSI seems to provide a single correlation which fits both western Canadian and Appalachian coals.

Blends to match proximate and petrographic properties seem to yield equal FSI.

CONCLUSIONS

1. Even though stored in dessicators at ice temperature, western Canadian coals exhibit aging, as measured by a decrease in total dilatation, over a 3-month period whereas Appalachian coals do not age over this time span.
2. western Canadian and Appalachian coking coals showing plastic properties and of equal rank yield dilatometric readings which differ by an order of magnitude even when larger top size and higher than standard heating rates are used.
3. Reducing top size from [-60] mesh to [-100] mesh decreases total dilatation of western Canadian and Appalachian by differing but still large amounts.
4. Surface areas of western Canadian and Appalachian coals overlap and do not explain dilatometry differences.
5. Even when coals of western Canadian and Appalachian origin are chosen to be identical is rank and very close is ash content, vitrinite levels and vitrinite reflectance, dilatation difference of almost an order of magnitude are seen.
6. Samples blended from either western Canadian or Appalachian coals to match inertite, semi-fusinite and vitrinite levels of target coals of the other origin still show dilatometric differences of 5X.
7. Plastometry using the Gieseler instruments gives separate correlations of ddpm against vitrinite content for western Canadian and Appalachian coals, and are related to dilatometric measurements in an exponential manner.

8. Only the FSI test yields a single correlation against vitrinite for both Appalachian and western Canadian coals, and only this test gave a match between target and blended coals.
9. Blend tests do not support hypothesis that the western Canadian and Appalachian dilatometric differences result solely from differences in the inertinite composition and the distribution of the inert components in the coal mass.
10. Serious consideration must be given to the possibility that vitrinite of coals of equal rank do not behave or dilatate equally during coking.

RECOMMENDATIONS

The problem under study in this and the previous contract has been divided in the INTRODUCTION and INTERPRETATION sections into two parts: (1) devising a rheology procedure that measures the coking potentials of Western Canadian and Appalachian coals adequately and (2) discovering the source of the rheological differences disclosed by the well established procedures. Recommendations will be split in the same way.

Two alternatives were proposed in the INTERPRETATION section. The first of these - altering test conditions of standard instruments to measure rheological values - involves correlating coke properties with rheological tests would require organizing a program of coke preparation at CANMET or with one or more coke producers. This will be required in the second alternative as well. It is an activity which should proceed only after discussion with industry and government coking specialists so action in the next year or two would be premature. We recommend this type of a program be undertaken only a few years from now.

The second alternative dealt with a new rheological test. Results in this study suggest that the new test should exploit the success of the Free Swelling Index test in providing a single correlation for both western Canadian and Appalachian coals and in matching blend values to target values. The FSI procedure employs high heating rates, large enough samples so temperature gradients exist, minimal compaction, a cooler region permitting condensation of volatiles on the sample. The procedure suffers from being qualitative. Figure 33 is the cross section of a proposed apparatus that will retain most of the FSI test conditions, but provided a quantitative measure, e.g. a dilatation. We recommend that a development study be undertaken on a FSI type test. The apparatus shown in Figure 33 could be a starting point.

Our conclusion that the rheological differences between the western Canadian and Appalachian coals lies in the reactive maceral, rather than the inerts, suggest a study of the reactives. We recommend a program of attempting to isolate vitrinite and exhibit from western Canadian and

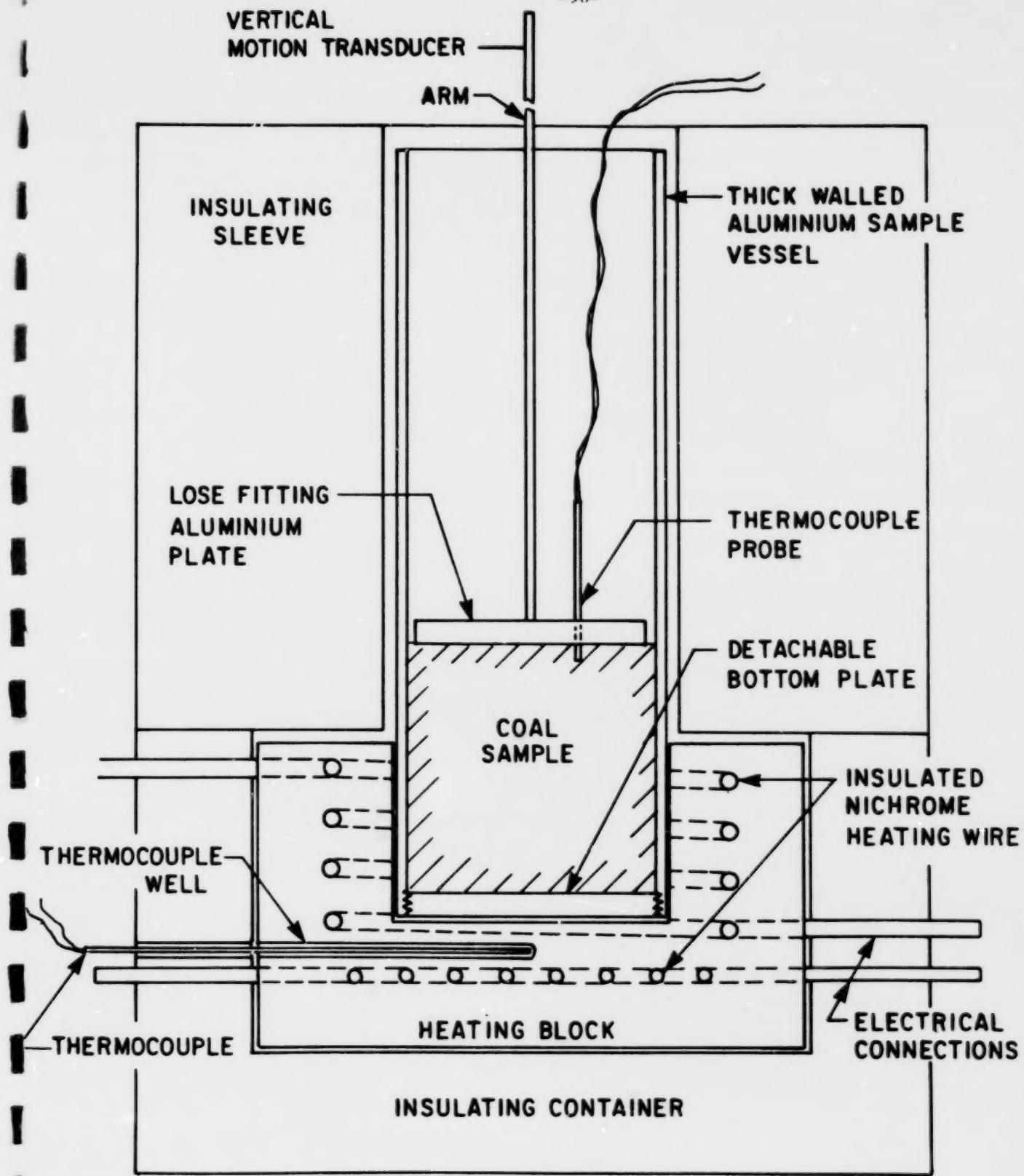


Figure 33: Proposed Rheology Test Unit

Appalachian coals in relatively pure form through application of the techniques applied by Van Krevelen and others. Not only rheological tests and ultimate analysis should be undertaken, but the behaviour of the macerals in swelling and under heating using a hot stage microscope should be undertaken. Experiments with the laser equipped petrographical unit now operating at Penn State should be considered.

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APPENDIX A

Raw Data from Part I - Aging Studies

Table A1
WESTERN CANADIAN COAL - WC4 (C/C)

	as received	AFTER					
		1 week	2 weeks	1 month	2 months	3 months	3 months
Softening Temp T_1 °C	396	407 (401) 396	417 (409) 394	415 (403) 390	404 (396) 393	410 (402) 396	412 (404) 391
Max. Contr. Temp T_2 °C	429	439 (433) 433	435 (434) 431	436 (434) 434	434 (434) 431	438 (435) 433	435 (434) 432
Max. Dilat. Temp T_3 °C	467	504 (486) 463	476 (469) 518	489 (504) 467	495 (480) 478	518 (496) 465	465 (465) 507
Max. Contraction % c	15.0	16.1 (15.5) 20.0	11.7 (15.9) 20.3	15.2 (17.7) 22.6	20.1 (21.3) 21.3	15.5 (18.4) 23.1	18.0 (20.5) 19.7
Max. Dilatation % d	61.7	53.2 (57.4) 61.7	75.0 (68.3) 69.5	74.6 (72.0) 61.3	67.2 (64.2) 61.7	63.8 (62.7) 54.5	59.0 (56.7) 57.4
c + d	76.7	69.3 (72.9) 81.7	86.7 (84.2) 89.8	89.8 (89.7) 83.9	87.3 (85.5) 83.0	79.3 (81.1) 77.6	77.0 (77.2) 77.1
G Factor	1.05	1.06 (1.06) 1.04	1.05 (1.05) 1.08	1.06 (1.07) 1.04	1.06 (1.05) 1.05	1.08 (1.06) 1.03	1.03 (1.03) 1.07

Conditions: Standard (3°C/min, 60 mesh top size, 4300 lbs/in² compaction)

() mean

Conditions: non-standard (3°C/min, [-60x100], 4300 lbs/in² compaction)

Table A1 (cont.)
WESTERN CANADIAN COAL - MC% (C/C)

		as received		1 week		2 weeks		After 1 month		2 months		3 months		3 months				
Softening Temp T_1 °C		380	414	(397)	393	403	(397)	386	411	(397)	398	413	(404)	396	392	417	(403)	395
Max. Contr Temp T_2 °C		429	427	(428)	425	428	(427)	424	430	(427)	426	432	(429)	429	432	435	(433)	432
Max. Dilat Temp T_3 °C		466	470	(468)	538	534	(536)	466	498	(480)	483	492	(487)	485	469	475	(471)	496
Max. Contraction % c		13.3	1.67	(7.5)	11.3	10.2	(10.7)	11.3	6.6	(8.9)	8.6	6.7	(7.6)	8.6	11.9	3.4	(7.6)	14.9
Max. Dilatation % d		85	100	(92.5)	80.7	94.9	(87.8)	87.1	96.7	(91.9)	100	106.7	(103.3)	75.9	59.3	71.2	(65.2)	57.2
c + d		98.3	101.7	(100.0)	92.0	105.1	(98.5)	98.4	103.3	(100.8)	108.6	113.4	(110.1)	84.5	71.2	74.6	(72.8)	72.1
G Factor		1.08	1.07	(1.08)	1.13	1.13	(1.13)	1.08	1.09	(1.08)	1.09	1.08	(1.09)	1.09	1.06	1.06	(1.07)	1.07

Conditions: Non-standard (3°C/min, 8 mesh top size, 4300 lbs/in² compaction)
() mean

Conditions: Non-standard: 3°C/min
[-60x100], 4300
lbs/in²

Table A1 (cont.)
WESTERN CANADIAN COAL - MC% (C/C)

18

		After					
		as received	1 week	2 weeks	1 month	2 months	3 months
							(AIB)
Softening Temp T_1 °C		389 409 (359) 397 404 (400) 397 421 (407) 408 408 (408) 419 411 (415) 401 412 (407) 395 415 (405)					
Max. Contr. Temp T_2 °C		429 429 (429) 434 438 (436) 429 429 (429) 428 437 (433) 436 440 (438) 436 433 (434) 435 439 (437)					
Max. Dilat Temp T_3 °C		476 476 (476) 475 475 (475) 475 475 (475) 478 478 (478) 477 477 (477) 476 472 (474) 475 475 (475)					
Max. Contraction % c		10.17 9.84 (10.0) 10.0 11.48 (10.7) 10.0 4.9 (7.5) 3.4 10.2 (6.9) 8.5 8.1 (8.3) 10.0 6.7 (8.3) 18.6 18.5 (18.5)					
Max. Dilation % d		113.6 123.0 (118.2) 118.3 113.1 (115.7) 131.7 132.8 (132.2) 106.8 123.7 (115.2) 97.7 89.9 (93.5) 83.3 85.0 (84.1) 67.8 79.0 (73.4)					
c + d		123.8 132.8 (128.2) 128.3 124.6 (126.4) 141.7 137.7 (139.7) 110.2 133.9 (122.1) 106.2 98.0 (101.8) 93.3 91.7 (92.4) 86.4 97.5 (91.9)					
G Factor		1.09 1.07 (1.08) 1.08 1.07 (1.08) 1.08 1.06 (1.07) 1.08 1.07 (1.08) 1.06 1.07 (1.06) 1.07 1.06 (1.07) 1.06 1.04 (1.05)					

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lbs/in² compaction)
() mean

Conditions: Non
Standard 4.5°C/min
[-60x100], 4300
lbs/in²

Table A1 (cont.)
WESTERN CANADIAN COAL - WC4 (Sample #2 C/C)

	as received	1 week	2 weeks	After			3 months (AIB)	3 months
				1 month	2 months	3 months		
Softening Temp T_1 °C	397 413 (405) 403 419 (411) 401 N/C (401) 405 422 (413) 399 419 (409) 390 412 (400) 395 418 (406)							
Max. Contr Temp T_2 °C	434 434 (434) 436 436 (436) 432 - (432) 438 434 (436) 432 435 (433) 432 436 (434) 435 439 (437)							
Max. Dilat Temp T_3 °C	476 480 (478) 478 487 (482) 475 475 (475) 474 474 (474) 474 474 (474) 468 476 (472) 467 523 (495)							
Max. Contraction % c	11.7 9.7 (10.7) 11.7 5.0 (8.3) 10.0 - (5.0) 8.3 3.3 (5.8) 10.0 4.9 (7.4) 13.3 6.9 (10.1) 19.3 11.8 (15.5)							
Max. Dilatation % d	108.3 133.9(121.1)111.7 131.7(121.7)113.3 121.3(117.3)103.3 108.3(105.8)116.7 111.5(114.1) 91.7 93.1 (92.4) 83.9 90.8 (87.3)							
c + d	120.0 143.6(131.8)123.4 136.7(130.0)123.3 - (122.3)111.6 111.6(111.6)126.7 116.4(121.5)105.0 100.0(102.5)103.2 102.6(102.8)							
G Factor	1.08 1.07 (1.07) 1.07 1.07 (1.07) 1.08 - (1.08) 1.07 1.06 (1.07) 1.08 1.06 (1.07) 1.07 1.07 (1.07) 1.06 1.09 (1.07)							

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lbs/in² compaction)

Conditions: Non
standard, 4.5°C/min
[-60x100], 4300
lbs/in²

Table A1 (cont.)
WESTERN CANADIAN COAL - WC4 (Sample #2 C/C)

	as received	After				
		1 week	2 weeks	1 month	2 months	3 months (A1B)
Softening Temp T_1 °C	391 391 (391) 393 418 (390) 392 413 (402) 395 407 (401) 387 404 (395) 394 394 (394) 390 409 (400)					
Max. Contr Temp T_2 °C	430 434 (432) 434 434 (434) 435 435 (435) 431 438 (434) 431 434 (432) 433 436 (434) 429 435 (432)					
Max. Dilat Temp T_3 °C	463 524 (493) 549 546 (547) 474 465 (470) 469 546 (508) 464 464 (464) 466 466 (466) 463 508 (486)					
Max. Contraction % c	23.3 24.6 (23.9) 22.9 15.0 (18.9) 22.4 18.6 (20.5) 19.7 20.0 (19.8) 22.0 20.3 (21.1) 22.2 24.2 (23.3) 20.8 18.5 (19.6)					
Max. Dilation % d	45.0 54.1 (49.5) 62.3 73.3 (67.8) 70.7 72.9 (71.8) 54.1 73.3 (63.7) 61.0 64.4 (62.7) 59.8 53.2 (56.5) 60.8 73.9 (67.3)					
c + d	68.3 78.7 (73.4) 85.2 88.3 (86.7) 93.1 91.5 (92.3) 73.8 93.3 (83.5) 83.0 84.7 (83.8) 82.0 77.4 (79.8) 81.6 92.4 (86.9)					
C Factor	1.03 1.06 (1.04) 1.08 1.10 (1.10) 1.05 1.04 (1.05) 1.04 1.09 (1.07) 1.04 1.04 (1.04) 1.04 1.03 (1.04) 1.04 1.07 (1.06)					

Conditions: Standard (3°C/min, 60 mesh top size, 4300 lbs/in²)

() mean

Conditions: Non
Standard (3°C/min
[-60x100], 4300
lbs/in² compaction)

Table A1 (cont.)
WESTERN CANADIAN COAL - WC4 (Sample #2 C/C)

	After as received	1 week	2 weeks	1 month	2 months	3 months	
Softening Temp T_1 °C	388	403 (394) 393	412 (402) 394	400 (397) 400	412 (406) 396	411 (403) 397	408 (402)
Max. Contr Temp T_2 °C	429	426 (428) 425	431 (428) 427	430 (429) 433	436 (434) 429	436 (433) 432	428 (430)
Max. Dilat Temp T_3 °C	545	473 (509) 465	471 (468) 533	470 (502) 466	508 (487) 498	469 (483) 542	536 (5398)
Max. Contraction % c	13.1	9.8 (11.4) 10.0	5.0 (7.5) 10.0	11.3 (10.6) 10.0	6.7 (8.3) 8.6	5.0 (6.8) 10.9	7.7 (9.3)
Max. Dilatation % d	90.2	98.4 (94.3) 95.0	105.0(100.0) 100.0	114.5(107.2)90.0	88.3 (89.2)	89.6 95.9 (92.7)81.2	86.1 (83.6)
c + d	103.3	108.2(105.7) 105.0	110.0(107.5)110.0	125.8(117.8)100.0	95.0(97.4)	98.2 100.9 (99.5)92.1	93.8 (92.9)
G Factor	1.14	1.07 (1.11) 1.07	1.06 (1.07) 1.14	1.07 (1.10) 1.06	1.10 (1.08) 1.10	1.06 (1.08) 1.13	1.13 (1.13)

Conditions: Non-standard (3°C/min, 8 mesh top size, 4300 lbs/in²)

Table A1
Dilatometric
WESTERN CANADIAN COAL - WCS (R/C)

	as received	After				
		1 week	2 weeks (AIB)	1 month	2 months	3 months
Softening Temp. T_1 °C	405 416 (411) 405 424 (416) 397 405 (402) 402 422 (411) 422 418 (420) 416 408 (412)					
Max. Contr. Temp. T_2 °C	442 442 (442) 442 448 (445) 439 445 (441) 439 447 (441) 441 447 (444) 441 441 (441)					
Max. Dilat. Temp. T_3 °C	474 505 (488) 478 507 (496) 491 538 (513) 470 495 (481) 478 540 (509) 528 470 (499)					
Max. Contraction % c	18.3 29.5 (23.9) 19.5 11.0 (15.2) 22.0 21.19(21.5) 20.3 10.9 (15.8) 8.1 19.2 (13.7) 9.88 12.69(11.29)					
Max. Dilatation % d	28.3 31.1 (29.9) 32.5 33.1 (32.8) 22.0 19.5 (20.7) 23.9 21.9 (22.9) 17.8 28.8 (23.3) 23.06 17.46(20.26)					
c + d	46.6 60.6 (53.8) 52.0 44.1 (48.0) 44.0 40.7 (42.2) 44.2 32.8 (38.7) 25.9 48.0 (37.0) 32.94 30.15(31.55)					
G factor	1.02 1.00 (1.01) 1.02 1.05 (1.03) 1.00 0.99 (1.00) 1.01 1.03 (1.02) 1.02 1.03 (1.03) 1.05 1.01 (1.03)					

Conditions: DIN Standard (3°C/min, 60 mesh top size, 4300 lb/in² compaction
() mean

Table A1 (cont.)
Dilatometric Results
WESTERN CANADIAN COAL - WC5 (R/C)

	as received (AIB)	After				
		1 week (AIB)	2 weeks	1 month (AIB)	2 months	3 months ./...
Softening Temp. T_1 °C	412 417 (415) 398 418 (408) 404 424 (414) 402 404 (408) 418 N/C 415 412 (414)					
Max. Contr. Temp. T_2 °C	438 440 (439) 432 438 (435) 436 441 (439) 440 436 (438) 430 N/C 441 438 (440)					
Max. Dilat. Temp. T_3 °C	502 466 (484) 471 508 (490) 522 524 (523) 470 495 (482) 521 499 (510) 509 465 (487)					
Max. Contraction % c	6.7 8.3 (7.5) 11.5 4.8 (8.1) 7.9 3.2 (5.5) 9.1 7.9 (8.5) 1.65 0 (0.83) 6.36 6.50 (6.43)					
Max. Dilation % d	40 53 (46.5) 42.6 43.2 (42.9) 42.8 44.4 (43.6) 34.8 47.6 (41.2) 29.8 41.0 (35.4) 30.21 42.28 (36.24)					
c + d	46.7 61.3 (54.0) 54.1 48.0 (51.0) 50.7 47.6 (49.2) 43.9 55.5 (49.7) 31.45 41.0 (36.2) 30.51 48.78 (39.64)					
G factor	1.08 1.04 (1.06) 1.05 1.08 (1.07) 1.10 1.10 (1.10) 1.05 1.08 (1.06) 1.11 / (1.10) 1.07 1.05 (1.06)					

Conditions: Non standard (3°C/min, 8 mesh top size, 4300 lbs/in² compaction)
() mean
N/C No Contraction

Table A1
Dilatometric Results
WESTERN CANADIAN COAL - WC5 (R/C)

	as received	1 week	2 weeks (A1B)	After 1 month	2 months	3 months (A/B)
Softening Temp. T_1 °C	406 414 (410) 400 424 (412) 405 422 (414) 403 423 (413) 411 423 (417) 419 N/C					
Max. Contr. Temp. T_2 °C	439 442 (440) 436 445 (441) 441 446 (443) 439 443 (441) 439 435 (437) 434 N/C					
Max. Dilat. Temp. T_3 °C	475 487 (481) 473 473 (473) 474 477 (476) 475 475 (475) 474 475 (475) 483 480 (482)					
Max. Contraction % c	9.7 11.3 (10.5) 11.4 6.6 (9.0) 9.6 9.5 (9.5) 9.5 7.7 (8.6) 8.5 1.6 (5.0) 1.64 0 (0.82)					
Max. Dilation % d	66.1 64.5 (65.3) 60.2 67.2 (63.7) 57.6 65.1 (61.3) 57.1 55.4 (56.2) 42.4 63.1 (52.7) 50.8 56.7 (53.7)					
c + d	75.8 75.8 (75.8) 71.6 73.8 (72.7) 67.2 74.6 (70.9) 66.6 63.1 (64.8) 50.9 64.7 (57.8) 52.5 56.7 (54.6)					
G factor	1.06 1.06 (1.06) 1.06 1.05 (1.06) 1.06 1.05 (1.06) 1.06 1.05 (1.06) 1.05 1.06 (1.06) 1.07 - (1.07)					

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lb/in² compaction
() mean
N/C No Contraction

Table A1 (cont.)
WESTERN CANADIAN COAL - WC6 (R/C)

	as received	1 week	2 weeks	After		3 months	After 3 months
				1 month	2 months (AIB)		AIB
Softening Temp. T_1 °C	383 399 (391)	N O	N O	404 401 (403)	393 405 (399)	415 410 (413)	397 405 (401)
Max. Contr. Temp. T_2 °C	427 430 (429)	D A	D A	432 423 (428)	428 434 (431)	429 429 (429)	428 428 (428)
Max. Dilat. Temp. T_3 °C	463 463 (463)	T A	T A	482 507 (495)	480 471 (476)	477 469 (473)	542 469 (503)
Max. Contraction % c	25.26 26.1 (25.6)	A	A	16.8 17.2 (17.0)	16.7 13.8 (15.3)	3.42 13.8 (8.61)	19.0 10.1 (14.5)
Max. Dilatation % d	68.9 83.5 (76.2)			82.5 89.7 (86.1)	76.7 83.0 (79.8)	65.0 72.4 (68.7)	81.0 85.7 (83.4)
c + d	94.2 109.6 (101.8)			99.3 106.9 (103.1)	93.4 96.8 (95.1)	68.4 86.2 (77.3)	100.0 95.8 (97.9)
G factor	1.05 1.04 (1.04)			1.06 1.09 (1.07)	1.07 1.06 (1.06)	1.07 1.05 (1.06)	1.11 1.06 (1.09)

Conditions: DIN Standard (3°C/min, 60 mesh top size, 4300 lb/in² compaction)
() mean

Conditions: Non-Standard (3°C/min, [-60x-100], 4300 lb/in² compaction)

Table A1 (cont.)

WESTERN CANADIAN COAL - WC6 (R/C)

	as received	1 week	2 weeks	After 1 month	2 months	(AIB)
Softening Temp. T_1 °C	387	399 (393)	N	393 397 (395)	400 N/C	391 402 (397)
Max. Contr. Temp. T_2 °C	422	430 (425)	O	420 417 (419)	417 N/C	416 421 (419)
Max. Dilat. Temp. T_3 °C	520	485 (503)	D	469 518 (494)	499 471 (485)	465 469 (467)
Max. Contraction % c	11.7	12.79(12.2)	A T	5.08 3.42 (4.3)	3.10 0 (1.55)	6.25 4.82 (5.54)
Max. Dilation % d	93.3	98.9 (96.7)	A	111.9 114.5(113.2)	103.9 111.9(107.9)	98.4 110.8(104.6)
c + d	105.0	111.7(108.3)		117.0 117.9(117.5)	107.0 111.9(109.5)	104.7 115.6(110.1)
G factor	1.13	1.08 (1.11)		1.09 1.14 (1.12)	1.12 - (-)	1.08 1.08 (1.08)

Conditions: Non Standard (3°C/min, 8 mesh top size, 4300 lb/in² compaction)
 () mean
 N/C No Contraction

Table A1 (cont.)

WESTERN CANADIAN COAL - WC6 (R/C)

	as received (AIB)	1 week	2 weeks	After		
				1 month	2 months (AIB)	3 months
Softening Temp. T_1 °C	374 403 (388)	N	N	385 399 (392)	405 402 (404)	404 430 (417)
Max. Contr. Temp. T_2 °C	427 434 (430)	O	O	422 426 (424)	424 428 (426)	423 434 (429)
Max. Dilat. Temp. T_3 °C	471 474 (472)	D	D	481 477 (479)	477 477 (477)	472 476 (474)
Max. Contraction % c	14.16 11.1 (12.6)	A	A	6.36 4.85 (5.61)	3.31 6.35 (4.83)	3.21 1.63 (2.42)
Max. Dilation % d	117.2 138.1 (127.6)	A	A	128.8 135.9 (132.3)	133.9 141.3 (137.6)	131.6 243.1 (137.4)
c + d	131.4 149.2 (140.3)			135.2 140.8 (138.9)	137.2 147.7 (142.4)	134.8 144.7 (139.8)
G factor	1.10 1.07 (1.09)			1.11 1.09 (1.10)	1.08 1.08 (1.08)	1.08 1.05 (1.07)

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lb/in² compaction)
() mean

Conditions: Non-
Standard (4.5°C/min
[-60x100], 4300
lb/in² compaction)

Table A1 (cont.)

APPALACHIAN COAL - AC3 (R/C)

	as received	1 week	2 weeks	After 1 month	2 months (AIB)	3 months
Softening Temp T_1 °C	369 382 (375)	380 405 (392.5)	378 387 (382)	380 399 (389.5)	365 397 (381)	376 389 (382)
Max. Contr Temp T_2 °C	416 422 (419)	414 417 (416)	418 421 (419)	417 417 (417)	414 420 (417)	403 403 (403)
Max. Dilat Temp T_3 °C	470 467 (469)	469 471 (470)	466 518 (492)	534 481 (508)	465 503 (484)	523 516 (520)
Max. Contraction % c	10.0 8.3 (9.1)	5.04 3.3 (4.2)	8.3 6.8 (7.5)	8.5 4.8 (6.6)	7.9 4.7 (6.3)	3.23 1.6 (2.4)
Max. Dilation % d	136.1 138.3 (137.2)	137.8 155.0 (146.4)	140. 157.6 (148.8)	130.5 142.8 (136.6)	137.0 145.3 (141.1)	148.9 166.7 (157.7)
c + d	146.1 146.6 (146.3)	142.8 158.3 (150.5)	148.3 164.4 (156.3)	139.0 147.6 (143.3)	144.9 150. (147.4)	152.1 168.3 (160.2)
G Factor	1.12 1.10 (1.11)	1.11 1.08 (1.10)	1.10 1.15 (1.12)	1.17 1.10 (1.13)	1.12 1.12 (1.12)	1.19 1.16 (1.18)

Conditions: Non Standard (3°C/min, 8 mesh top size, 4300 lb/in² compaction)

Table A1 (cont.)

APPALACHIAN COAL - AC3 (R/C)

	as received	1 week	2 weeks	After 1 month	2 months	3 months
Softening Temp T_1 °C	397 412 (405) 408 397 (402) 389 403 (396) 397 409 (403) 391 405 (397) 376 400 (388)					
Max. Contr Temp T_2 °C	425 425 (425) 427 429 (428) 423 427 (425) 427 427 (427) 429 429 (429) 415 421 (418)					
Max. Dilat Temp T_3 °C	506 462 (484) 463 469 (466) 462 483 (472) 533 461 (497) 462 462 (462) 534 467 (501)					
Max. Contraction % c	16.4 16.7 (16.5) 16.7 16.3 (16.5) 16.8 17.1 (16.9) 6.7 14.2 (10.5) 18.3 16.8 (17.5) 14.8 9.9 (12.3)					
Max. Dilation % d	42.6 46.7 (44.6) 46.6 45.5 (46.0) 47.1 46.1 (46.6) 43.3 42.5 (42.9) 45.0 43.7 (44.4) 85.2 33.8 (89.5)					
c + d	59.0 63.4 (61.2) 63.3 61.8 (62.5) 63.9 63.2 (63.5) 50.0 56.7 (53.4) 63.3 60.5 (61.9) 100. 103.7 (101.8)					
G Factor	1.06 1.03 (1.04) 1.03 1.04 (1.04) 1.04 1.04 (1.04) 1.12 1.03 (1.07) 1.04 1.03 (1.03) 1.14 1.07 (1.10)					

Conditions: DIN Standard (3°C/min, 60 mesh top size, 4300 lb/in² compaction
() mean

Table A1 (cont.)

APPALACHIAN COAL - AC3 (R/C)

	as received	1 week	2 weeks	After 1 month (A/B)	2 months	3 months
Softening Temp. T_1 °C	380 396 (388)	380 378 (379) 384 391 (387.5)	377 387 (382)	382 390 (386)	380 413 (396)	370 373 (372)
Max. Contr. Temp. T_2 °C	421 421 (421)	425 425 (425) 419 427 (423)	417 422 (420)	417 421 (419)	421 428 (424)	411 411 (411)
Max. Dilat. Temp. T_3 °C	479 524 (501.5)	529 529 (501) 489 489 (489)	483 475 (479)	474 478 (476)	476 476 (476)	482 477 (480)
Max. Contraction % c	8.3 5.0 (6.6)	8.2 8.1 (8.2) 5.5 8.3 (6.9)	8.3 6.8 (7.5)	8.1 6.4 (7.2)	6.5 3.3 (4.9)	1.59 3.4 (2.5)
Max. Dilatation % d	155.0 176.7 (165.9)	152.5 177.4 (164.9) 158.3 181.7 (170)	180 174.6 (177.3)	172.8 (173.5)	165.8 168.8 (167.3)	192.4 191.6 (192.)
c + d	163.3 181.7 (172.5)	160.7 185.5 (173.1) 163.8 190.0	188.3 181.4 (184.8)	182.3 179.2 (180.7)	172.3 172.1 (172.2)	194.0 195 (194.5)
G Factor	1.12 1.15 (1.13)	1.11 1.18 1.14 1.13 1.10 (1.12)	1.11 1.10 (1.11)	1.10 1.10 (1.10)	1.12 1.07 (1.10)	1.15 1.14 (1.14)

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lbs/in² compaction
() mean value

Table A1 (cont)
APPALACHIAN COAL - AC3 (C/C)

	as received	1 week	2 weeks	After 1 month	2 months	3 months (AIB)
Softening Temp T_1 °C	N O	N O	N O	364 382 (373) 364 373 (370) 360 366 (363)		
Max. Contr Temp T_2 °C	D A T	D A T	D A T	404 404 (404) 398 401 (400) 395 402 (399)		
Max. Dilat Temp T_3 °C	A	A	A	482 477 (480) 490 483 (487) 490 486 (488)		
Max. Contraction % c				11.5 9.8 (10.6) 9.5 8.2 (8.8) 6.35 6.35 (6.35)		
Max. Dilation % D				257.4 268.8 (263.1) 279.6 298.4 (286.5) 273 290.5 (281.7)		
c + d				268.9 272.6 (273.7) 289.1 306.6 (295.3) 279.4 296.9 (288.1)		
G Factor				1.15 1.11 (1.13) 1.16 1.14 (1.15) 1.17 1.16 (1.16)		

Conditions: Standard (4.5°C/min, 8 mesh top size, 4300 lb/in² compaction

() mean

Table A1 (cont.)
APPALACHIAN COAL - AC3 (C/C)

	as received	1 week	2 weeks	After 1 month	2 months	3 months
Softening Temp. T_1 °C	N O	N O	N O	355 367 (360) 355 362 (357) 365 355 (360)		
Max. Contr Temp T_2 °C	D A T A	D A T A	A A T A	403 403 (403) 399 402 (401) 391 391 (391)		
Max. Dilat Temp T_3 °C				507 475 (493) 476 475 (476) 481 514 (498)		
Max. Contraction % c				13.3 10.0 (11.6) 11.3 12.5 (11.9) 6.5 9.7 (8.1)		
Max. Dilatation % d				240.0 253.3 (246.6) 225.8 245.3 (235.5) 248.4 271 (259.7)		
c + d				253.3 263.3 (258.2) 237.1 257.8 (247.4) 254.9 280.7 (267.8)		
G Factor				1.19 1.13 (1.17) 1.15 1.14 (1.15) 1.15 1.21 (1.18)		

Conditions: Non standard (3°C/min, 8 mesh top size, 4300 lb/in² compaction
() mean

Table A1 (cont.)
APPALACHIAN COAL - AC3 (C/C)

	as received	1 week	2 weeks	After 1 month (AIB)	2 months (AIB)	3 months (AIB)
Softening Temp. T_1 °C	N O	N O	N O	354 373 (362) 354 366 (358) 360 370 (366)		
Max. Contr Temp T_2 °C	D A T A	D A T A	D A T A	405 409 (407) 405 411 (408) 403 405 (404)		
Max. Dilat Temp T_3 °C	A	A	A	472 472 (472) 472 472 (472) 488 476 (482)		
Max. Contraction % c				22.9 22.9 (22.9) 25.2 19.2 (22.2) 15.0 15.5 (15.3)		
Max. Dilatation % d				201.6 218.0(209.8)201.6 212.8(207.2)230.0 246.5(238.3)		
c + d				224.5 240.9(232.7)226.8 232.0(229.4)245.0 262.0(253.6)		
G Factor				1.13 1.10 (1.12) 1.13 1.12 (1.13) 1.15 1.12 (1.14)		

Conditions: Standard (3°C/min, 60 mesh top size, 4300 lbs/in² compaction)
() mean

Table A1 (cont.)
APPALACHIAN COAL - AC4 (R/C)

	as received	1 week	2 weeks	After 1 month (AIB)	2 months	3 months
Softening Temp. T_1 °C	374 376 (375)	366 388 (377)	368 373 (370)	368 380 (375)	378 (371)	376 374 (375)
Max. Contr. Temp. T_2 °C	416 420 (418)	414 417 (416)	411 417 (414)	413 413 (413)	410 418 (415)	414 414 (414)
Max. Dilat Temp T_3 °C	505 467 (486)	469 478 (474)	471 476 (474)	531 475 (508)	544 503 (523)	543 470 (507)
Max. Contraction % c	23.3 22.0 (22.7)	19.7 18.0 (18.8)	21.8 22.9 (22.3)	22.0 25.4 (23.7)	23.3 14.7 (19.0)	16.1 19.8 (17.97)
Max. Dilatation % d	128.3 125.4 (126.9)	137.7 118.0 (127.8)	112.6 132.8 (122.0)	118.6 118.6 (118.6)	106.7 104.9 (105.8)	132 148.8 (140.4)
c + d	151.6 147.4 (149.5)	157.4 136 (146.7)	134.4 155.7 (144.3)	140.6 144.0 (142.3)	130 119.6 (124.8)	148.1 168.6 (158.4)
G Factor	1.12 1.08 1.10 (1.09)	1.10 1.08 (1.09)	1.09 1.09 (1.09)	1.14 1.08 (1.11)	1.15 1.12 (1.13)	1.17 1.10 (1.13)

Conditions: Standard (3°C/min, 60 mesh top size, 4300 lbs/in² compaction)
() mean

Table A1 (cont.)
APPALACHIAN COAL - AC4 (R/C)

	as received	1 week	2 weeks	After 1 month (AIB)	2 months (AIB)	3 months						
Softening Temp. T_1 °C	374	385 (379)	367	383 (375)	371	379 (375)	381	384 (382)	370	387 (379)	375	N/C
Max. Contr Temp T_2 °C	416	419 (418)	415	415 (415)	417	417 (417)	415	418 (416)	412	421 (416)	399	N/C
Max. Dilat Temp T_3 °C	481	509 (495)	471	500 (485)	469	471 (470)	523	484 (504)	508	471 (489)	541	474 (508)
Max. Contraction % c	10.0	6.7 (8.3)	11.7	8.3 (10.0)	10.0	6.6 (8.3)	10.0	9.8 (9.9)	11.5	8.2 (9.8)	3.25	0 (1.63)
Max. Dilatation % d	135	148.3(141.6)	141.7	151.7(146.7)	128.3	152.5(140.4)	125	141 (133)	131.1	147.5(139.3)	152.8	162.4(157.6)
c + d	145	155 (150)	153.4	160 (156.7)	138.3	159.1(148.7)	135.0	150.8(142.9)	142.6	155.7(149.1)	156.1	162.4(159.2)
G Factor	1.12	1.15 (1.13)	1.12	1.13 (1.12)	1.11	1.11 (1.11)	1.15	1.11 (1.13)	1.15	1.10 (1.12)	1.21	-

Conditions: Non standard (3°C/min, 8 mesh top size, 4300 lbs/in² compaction)
() mean

Table A1 (cont.)
APPALACHIAN COAL - AC4 (R/C)

	as received	1 week	2 weeks	After 1 month	2 months	3 months (A1B)
Softening Temp T ₁ °C	388 381 (385)	359 394 (373)	371 396 (381)	386 382 (384)	367 408 (387)	374 380 (377)
Max. Contr Temp T ₂ °C	416 420 (418)	413 417 (415)	416 420 (418)	415 418 (417)	415 423 (419)	402 417 (409)
Max. Dilat Temp T ₃ °C	485 517 (501)	478 478 (478)	477 512 (494)	474 474 (474)	474 478 (476)	480 480 (480)
Max. Contraction % c	3.4 10.0 (6.7)	8.3 6.8 (7.5)	8.6 5.1 (6.8)	8.8 11.8 (10.3)	11.1 3.2 (7.1)	5.00 4.92 (4.96)
Max. Dilatation % d	176.3 176.7 (176.5)	171.7 188.1 (179.9)	172.4 183.0 (177.7)	161.4 173.1 (167.2)	152.1 169.3 (160.7)	180.0 188.5 (184.3)
c + d	179.7 186.7 (183.2)	180.0 194.9 (187.4)	181.0 188.1 (184.5)	170.2 184.9 (177.5)	163.2 172.5 (167.8)	185.0 193.4 (189.2)
G Factor	1.12 1.16 (1.14)	1.15 1.10 (1.13)	1.13 1.14 (1.13)	1.10 1.10 (1.10)	1.12 1.08 (1.10)	1.13 1.12 (1.13)

Conditions: Non standard (4.5°C/min, 8 mesh top size, 4300 lbs/in² compaction)
() mean

Table A2
Comparison of Standard and Non-Standard Rheological Tests

All values obtained from testing at three months

Condition Mesh Temp. Rate (°C/min) 4300 psi compaction pressure	WC5 (R/C)			WC6 (R/C)			WC4 (C/C)		
	S [-60] 3	NS [-60x 100] 3	NS [-8] 4.5	S [-60] 3	NS [-60x 100] 3	NS [-8] 4.5	S [-60] 3	NS [-60x 100] 3	NS [-8] 4.5
Softening Temp T ₁ °C	416 408 (412)	419 439 (429)	419 N/C (419)	415 410 (413)	397 405 (401)	404 430 (417)	404 394 (399)	395 400 (398)	407 400 (404)
Max. Contr. Temp T ₂ °C	441 441 (441)	442 448 (445)	434 N/C (434)	429 429 (429)	428 428 (428)	423 434 (429)	434 434 (434)	432 432 (432)	434 434 (434)
Max. Dilat. Temp T ₃ °C	528 470 (499)	475 497 (486)	483 480 (482)	477 469 (473)	542 464 (503)	472 476 (474)	465 466 (466)	496 486 (491)	474 472 (473)
Max. Contraction % c	9.9 12.7 (11.3)	6.56 1.65 (4.10)	1.64 0 (0.82)	3.42 13.8 (8.61)	19.0 10.1 (14.5)	3.21 1.63 (2.42)	20.5 23.3 (21.9)	14.9 19.6 (17.3)	8.3 10.1 (9.2)
Max. Dilatation % d	23.1 17.5 (20.3)	4.91 4.96 (4.94)	50.8 56.7 (53.7)	65.0 72.4 (68.7)	81.0 85.7 (83.4)	131.6 143.1 (137.4)	56.7 56.5 (56.6)	57.2 67.3 (62.3)	84.1 92.4 (88.3)
c + d	32.9 30.2 (31.6)	11.5 6.61 (9.04)	52.5 N/C (54.5)	68.4 86.2 (77.3)	100.0 95.8 (97.9)	134.8 144.7 (139.8)	77.2 79.8 (78.5)	72.1 86.9 (79.5)	92.4 102.5 (97.5)
G-Factor	1.05 1.01 (1.03)	0.99 1.03 (1.01)	1.07 N/C (1.07)	1.07 1.05 (1.06)	1.11 1.06 (1.09)	1.08 1.05 (1.07)	1.03 1.04 (1.03)	1.07 1.06 (1.07)	1.07 1.07 (1.07)

Table A2 (cont.)

All values obtained from testing at three months

Condition	AC4 (R/C)			AC3 (R/C)			AC3 (C/C)		
	S	NS	NS	S	NS	NS	S	NS	NS
Mesh	[-60]	[-60x 100]	[-8]	[-60]	[-60x 100]	[-8]	[-60]	[-60x 100]	[-8]
Temp. Rate (°C/min)	3	3	4.5	3	3	4.5	3	3	4.5
4300 psi compaction pressure									
Softening Temp T_1 °C	376 374 (375)	382 382 (382)	374 380 (377)	375 385 (380)	376 400 (389)	370 373 (372)	362 370 (366)	375 369 (372)	360 366 (363)
Max. Contr. Temp T_2 °C	414 414 (414)	415 418 (417)	402 417 (409)	414 421 (418)	415 421 (418)	411 411 (411)	403 405 (404)	410 410 (410)	395 402 (399)
Max. Dilat. Temp T_3 °C	543 470 (507)	470 476 (473)	480 480 (480)	477 477 (477)	534 467 (501)	482 477 (480)	488 476 (482)	477 477 (477)	490 486 (488)
Max. Contraction % c	16.1 19.8 (17.97)	10.1 17.4 (13.7)	5.00 4.92 (4.96)	13.4 13.4 (13.4)	14.8 9.9 (12.3)	1.59 3.40 (2.5)	15.0 15.5 (15.3)	12.1 17.2 (14.7)	6.35 6.35 (6.35)
Max. Dilatation % d	132.0 148.8 (140.4)	151.3 173.9 (162.5)	180.0 188.5 (184.3)	178.2 198.3 (188.2)	85.2 93.8 (89.5)	128.6 137.6 (133.1)	230.0 246.5 (238.3)	237.9 255.2 (246.6)	273.0 290.5 (281.7)
c + d	148.1 168.6 (158.4)	161.4 191.3 (176.2)	185.0 193.4 (189.3)	191.6 211.7 (201.6)	100.0 103.7 (101.8)	142.9 152.0 (147.4)	245.0 262.0 (253.6)	250.0 272.4 (261.3)	279.4 296.9 (288.1)
G-Factor	1.17 1.10 (1.13)	1.10 1.10 (1.10)	1.13 1.12 (1.13)	1.11 1.10 (1.10)	1.13 1.07 (1.10)	1.16 1.08 (1.12)	1.15 1.12 (1.14)	1.12 1.13 (1.12)	1.17 1.16 (1.16)

Table A3
Gieseler Plastometry Measurements

Coal	Mesh	Heating Rate	Run #	T _s (°C)	T _{fusion} (°C)	T _{fluid} (°C)	Max. Fluid ddpm	T _{final} (°C)	T _{solid} (°C)	Remarks
AC3 (C/C)	[-8]	3°C/min	1	408.9	416.8	455.0	5177.6	498.0	503.6	Coal cleaned with Certigrav 1.42 s.g.
			2	411.7 (410.3)	421.8 (419.3)	447.0 (451.0)	14900.5 (10039.0)	493.6 (495.8)	506.6 (505.1)	Coal freshly ground
	[-8]	4°C/min	1	415.5	423.8	451.6	22310.6	503.9	509.8	Coal freshly ground
			2	410.6 (413.1)	419.9 (421.9)	454.2 (452.9)	22913.7 (22612.0)	501.3 (502.6)	509.5 (509.7)	Coal freshly ground
	[-35]	3°C/min 4°C/min	1	402.1	417.1	447.0	14173.8	492.4	503.1	Coal freshly ground
			2	398.8	416.5	461.1	28603.0	496.9	507.5	
AC3 (R/C)	[-35]	4°C/min 3°C/min	1	399.0	416.6	410.4	15309.6	489.5	503.5	
			2	399.8	408.5	437.5	4512.1	483.4	490.2	
AC4 (R/C)	[-8]	3°C/min	1	412.2	421.5	455.9	3930.7	495.7	503.2	Coal freshly ground
			2	409.6 (410.6)	422.2 (421.9)	452.4 (454.2)	3223.3 (3577.0)	499.9 (497.8)	507.3 (505.3)	Coal freshly ground
	[-8]	4°C/min	1	416.9	425.2	459.5	4906.0	509.6	512.9	Coal freshly ground
			2	416.4 (416.7)	426.6 (425.9)	460.1 (459.8)	6782.8 (5844.0)	508.1 (508.9)	516.0 (514.5)	Coal freshly ground
	[-35]	3°C/min	1	403.2	416.1	462.0	2858.2	498.4	505.9	Coal freshly ground
			2	410.5 (406.9)	423.5 (419.8)	452.8 (457.4)	3832.2 (3345.0)	497.8 (498.1)	503.7 (504.8)	Coal freshly ground
[-35]	4°C/min	4°C/min	1	409.0	419.8	464.7	4313.3	506.7	511.4	Coal freshly ground
			2	410.2 (409.6)	425.8 (422.8)	462.2 (463.5)	4600.9 (4457.0)	506.5 (506.6)	514.3 (512.9)	Coal freshly ground

Table A3 (cont.)

Coal	Mesh	Heating Rate	Run #	T _s (°C)	T _{fusion} (°C)	T _{fluid} (°C)	Max. Fluid ddpm	T _{final} (°C)	T _{solid} (°C)	Remarks
WCS (R/C)	[-8]	3°C/min	1	443.2	448.1	465.9	141.2	496.8	503.8	After 3 months
			2	446.2 (444.7)	449.5 (448.8)	472.6 (469.3)	204.6 (172.9)	495.8 (496.3)	502.9 (503.4)	
	[-8]	4°C/min	1	440.6	449.2	476.0	274.9	503.3	513.4	
			2	441.0 (440.8)	452.0 (450.6)	478.2 (477.1)	233.7 (254.3)	507.8 (505.6)	517.4 (515.4)	
	[-35]	3°C/min	1	432.8	447.3	470.9	63.5	488.7	505.5	Crucible cleaned with rifle-bore solvent for both runs
			2	432.4 (432.6)	447.5 (447.4)	471.2 (471.1)	103.8 (83.7)	491.8 (490.3)	500.6 (503.1)	
	[-35]	4°C/min	1	433.9	448.0	479.3	146.7	484.0	487.1	
			2	433.4 (433.7)	448.6 (448.3)	478.5 (478.9)	197.5 (172.1)	492.8 (488.4)	483.7 (485.4)	
WCA (C/C)*	[-8]	3°C/min	1	434.0	444.1	461.5	115.3	485.0	497.1	Coal Freshly Ground Soldier in crucible; data ignored Coal freshly ground
			2	433.0	442.8	460.5	115.7	488.2	496.4	
			3	434.8	443.2	464.9	137.8	488.0	500.5	
			4	431.6	443.2	460.4	230.9	489.3	498.3	
			5	425.6 (431.9)	437.8 (442.0)	460.8 (461.9)	175.2 (136.0)	491.2 (488.9)	493.0 (496.8)	
	[-8]	4°C/min	1	438.6	446.2	470.1	284.7	497.0	506.0	Coal freshly ground
			2	435.7	447.1	472.0	202.6	493.1	489.5	Coal freshly ground
			3	435.4 (436.6)	441.0 (444.8)	474.6 (472.2)	253.3 (246.9)	494.2 (494.8)	505.5 (500.3)	Coal freshly ground
	[-35]	3°C/min	1	429.0	443.6	463.7	108.0	487.8	499.3	
			2	425.7	439.5	463.4	112.3	484.0	501.1	
			3	429.9	442.9	462.5	111.5	489.4	497.0	
			4	428.7 (428.3)	441.0 (441.8)	464.0 (463.4)	107.6 (109.9)	488.6 (487.5)	496.8 (498.6)	

Table A3 (cont.)

Coal	Mesh	Heating Rate	Run #	T _s (°C)	T _{fusion} (°C)	T _{fluid} (°C)	Max. Fluid ddpm	T _{final} (°C)	T _{solid} (°C)	Remarks
WC4 (R/C)	[-35]	3°C/min 4°C/min		428.9 438.0	443.1 452.3	456.9 465.0	11.7 9.5	472.8 482.7	483.2 491.0	
WC4 (C/C)	[-35]	4°C/min	1 2 3	426.5 433.7 432.6 (430.9)	441.8 445.8 445.7 (444.4)	471.5 470.6 473.8 (472.0)	175.4 175.1 185.8 (178.8)	495.8 479.3 500.0 (491.7)	506.0 498.2 509.2 (504.5)	Coal freshly ground Coal freshly ground Coal freshly ground
WC6 (R/C)	[-8]	3°C/min	1 2	426.8 429.6 (428.2)	441.0 437.2 (439.1)	461.7 463.4 (462.6)	231.8 146.8 (189.3)	481.9 485.1 (483.5)	496.0 487.1 (491.6)	
	[-8]	4°C/min	1 2	434.3 434.4 (434.4)	443.3 440.2 (441.8)	467.3 463.6 (465.5)	336.7 359.0 (347.9)	496.5 493.5 (495.0)	501.6 497.3 (499.5)	
	[-35]	3°C/min	1 2	425.1 429.5 (427.3)	438.5 437.5 (438.0)	462.8 466.3 (464.6)	138.9 130.8 (134.9)	485.1 483.2 (484.2)	500.8 493.3 (497.1)	
	[-35]	4°C/min	1 2	432.0 425.1 (428.6)	444.7 437.7 (441.2)	471.4 460.9 (466.2)	213.8 257.2 (235.5)	495.3 488.9 (492.1)	505.2 501.9 (503.6)	

T_i: Initial softening temperature: T @ 1.0 ddpm (All in °C)T_s: fusion temperature: T @ 5.0 ddpmT_{fusion}: maximum fluid temperature: max. ddpmT_{fluid}: final temperature: T @ 1.0 ddpmT_{final}: solidification temperature: T @ 0.0 ddpmT_{solid}:

Table A4
FSI Measurements

Coal	Run #	Mesh	As rec'd	After 3 months	After 3 months [-60x100] mesh
<u>Western Canadian</u>					
WC5 (R/C)	1	[-60]	8	7½	5
	2	"	ND	8 (8)	5 (5)
WC5 (R/C)	1	[-100]	9		
	2	"	9	ND	ND
	3	"	8½ (9)		
WC6 (R/C)	1	"	8	7	3
	2	"	ND	7½ (7½)	4 (3½)
WC4 (R/C)	1	"	4	4	8
	2	"	ND	4 (4)	8 (8)
WC4 (C/C)	1	"	4½	8	7½
	2	"	ND	8 (8)	8 (7½)
<u>Appalachian</u>					
AC3 (R/C)	1	"	7	6½	
	2	"	ND	5½ (6)	ND
AC3 (C/C)	1	"	8	7	
	2	"	ND	7½ (7½)	ND
AC4 (R/C)	1	"	8	8	
	2	"	ND	8½ (8½)	ND
AC4 (R/C)	1	"	9		
	2	"	8½	ND	ND
	3	"	8½ (8½)		

Table A5
Proximate Analyses and Sulfur

Coal	Moisture	Proximate Analysis (db%)			Fixed Carbon	Sulfur (db%)
		Ash	Volatile Matter			
<u>Western Canadian</u>						
WC6 (R/C)	0.67	8.00	28.4	63.68	1.05	
WC5 (R/C)	0.33	8.44	23.0	68.6	1.53	
WC4 (R/C)*	0.79	25.00	22.0	53.0	1.76	
WC4 (C/C)*	1.71	4.79	25.9	69.3	2.16	
<u>Appalachian</u>						
AC4	0.31	17.9	23.41	58.7	0.57	
AC3	0.56	29.7	22.4	47.9	1.21	
AC3	1.00	5.02	30.7	64.3	0.93	

* Average of Samples 1 and 2

Table A5 (cont.)
Proximate Analysis of Sieved Coal

Coal	Mesh	Moisture	Proximate Analysis		Fixed Carbon (Average Value)
			Ash	Volatile Matter	
WC6	[-60x-100]	1.106 1.027 0.9445 (1.026)	7.903	28.076	
			8.139	28.420	
			8.038 (8.027)	27.743 (28.080)	
			8.11 db%	28.4 db%	63.5 db%
WC5	[-60x-100]	0.3041 0.3837 0.2968 (0.3282)	8.449	22.026	
			8.2976	21.745	
			8.1118 (8.286)	22.116 (21.962)	
			8.31 db%	22.0 db%	69.7 db%
WC4	[-60x-100]	1.1486 1.1709 (1.1597)	4.271	27.040	
			4.125	26.615	
			4.198	(26.828)	
			4.25 db%	27.1 db%	68.7 db%
AC4	[-60x-100]	0.5861 0.5138 (0.54997)	17.073	24.171	
			17.149	22.875	
			(17.111)	(23.523)	
			17.2 db%	23.7 db%	59.1 db%

() = mean

Table A6

Ultimate Analysis

COAL SAMPLE

Component	AC3		AC4		WC4 (Sample 1) C/C		WC4 (Sample 2) C/C		WC6		WC5	
	C/C	R/C	R/C	R/C					R/C		R/C	
C(%) daf	84.84	61.67	73.83	89.93	86.04	85.66	85.66	79.95	81.84	89.35		
	89.27	87.72			90.37	90.10		86.85				
H(%)	4.93	3.84	4.17		4.80	4.90		4.82	4.50			
N(%)	1.72	1.44	1.99		1.29	0.71		1.34	1.47			
S(%)	0.93	1.21	0.57		2.16	2.73		1.05	1.53			
O(%) (daf)	2.62	2.15	1.54		0.91	1.07		4.89	2.24	2.45		
	2.76	3.06	1.88		0.96	1.13		5.31				
Ash (%)	4.97	29.70	17.90		4.79	4.93		7.95	8.41			

* All % are db (dry basis) unless noted

Table A7

PETROGRAPHIC ANALYSIS

Coal	Reactive Components %				Inert Components %				Petrographic Indices and Coke Indices					
	Vitrinite	S. Fusinite	Exinite	Total	S. Fusinite	Microinite	Fusinite	Mineral Matters	Total	Random No	Max. No	Balance Index	Strength Index	Stability Index
<u>Western Canadian</u>														
WCS (row)	74.5	4.2	0.0	80.8	8.5	1.6	4.5	4.6	19.2		1.2	0.85	4.64	61.60
WCS (row)	40.6	12.5	0.0	53.1	25.3	5.5	11.1	5.0	46.9	1.08		1.97	3.90	40.50
WCS (clean)											1.14	2.16	4.07	41.10
WCS (clean) (sample 1)	68.0	4.5	0.9	73.4	9.1	10.5	4.1	2.9	26.6	1.05		1.02	4.11	56.40
Sample 2	67.3	5.3	0.5	73.1	10.6	7.8	4.8	3.7	26.9	1.05	1.08	1.06	4.15	56.60
Average	67.65	4.90	0.70	73.25	9.85	9.15	4.45	3.30	26.75			0.98	3.92	53.90
<u>Appalachian</u>														
AC3 (row)	57.0	1.9	3.6	63.1	3.9	10.0	4.2	18.8	36.9	1.05		1.46	3.80	46.30
AC3 (clean)	72.4	2.7	3.9	79.0	5.3	9.8	3.0	2.9	21.0	1.03		0.65	3.76	49.50
AC3 (row)	40.9	4.7	5.7	51.3	9.4	20.9	7.9	10.5	48.7	1.07	1.05	0.66	3.86	51.20
											1.12	2.45	3.90	26.10
												2.58	3.80	31.40

Table A8
Microfossil Type Analysis

COL	WC4 (Sample 1)				WC4 (Sample 2)				WC5				WC6			
	121	122	Mean		118	117	Mean		129	130	Mean		130	131	Mean	
pellet no.																
Liptite	-	-	-		-	-	-		-	-	-		-	-	-	
Clarite	2	-	(1)		-	-	-		1	-	(0.5)		3	4	(3.5)	
Vitrite	41	46	(43.5)		37	43	(40)		17	22	(19.5)		55	57	(56)	
Inertite (I)	8	9	(8.5)		9	8	(8.5)		20	22	(21)		5	8	(6.5)	
SF	2	4			3	2			9	10			3	5		
F	3	2			4	-			5	2			2	1		
M	1	1			1	1			1	3			-	2		
Vitrinite	37	42	(39.5)		43	36	(39.5)		54	48	(51)		33	27	(30)	
Trinacrite	10	3	(6.5)		10	13	(11.5)		7	8	(7.5)		3	3		
Cladurite I>I+E	10	3			10	12			7	8			1	3	(3)	
duroclarite V>I+E	-	-			-	1			-	-			2	-		
vitrinertoliptite E>I+I	-	-			-	-			-	-			-	-		
Durite	2	-	(1)		1	-	(0.5)						1	1	(1)	
Totals	100	100	100		100	100	100		100	100	100		100	100	100	

All numbers are %

() mean

Table A8 cont'd
Micro lithotype Analysis

CONL	AC3 (R/C)			AC3 (C/C)			AC4		
	126	125	Mean	127	128	Mean	123	124	Mean
Pellet no.									
Liptite	-	-	-	-	-	-	-	-	-
Clarite	9	2	(5.5)	7	5	(6)	4	2	(3.5)
Vitrite	46	35	(40.5)	36	47	(41.5)	24	23	(23.5)
Inertite (I)	10	10	(10)	5	3	(4)	20	20	(20)
SF	6	4		2	2		5	2	
F	2	3		1	-		3	8	
M	2	2		-	-		4	5	
Vitrinertite	28	36	(32)	45	35	(40)	28	32	(30)
Trinocerite	6	14	(10)	6	9	(7.5)	17	14	(15.5)
Clarodurite > V+E	4	9		4	5		8	11	
duroclartite > V+E	2	2		1	3		6	2	
vitrinertoliptite > V+E	-	1		1	2		3	1	
Durite	1	1	(1)	1	1	(1)	7	8	(7.5)
Totals	100	100	(100)	100	100	100	100	100	100

All numbers are %

() = mean

Table A9
Sieve Analysis

Coal	[+4] ([-4])	PARTICLE TOP SIZE (WT%)						
		[-4]	[-6]	[-10]	[-20]	[-60]	[-100]	[-270]
<u>Western Canadian</u>								
WC9 (raw)	6.73	4.85	12.14	14.15	27.04	13.72	13.7	7.67
WC8 (raw)	20.96	6.75	14.80	14.76	22.03	8.79	10.92	0.99
WC7 (raw) (sample 1)	13.52	10.50	23.48	18.65	19.73	4.83	5.85	3.44
WC7 (raw) (sample 2)	28.90	11.31	19.21	14.37	15.10	4.11	4.48	2.50
WC7 (clean) (sample 1)	7.43	12.31	27.93	21.56	20.80	4.50	4.17	1.29
WC7 (clean) Sample 2	12.30	10.09	25.15	20.13	20.56	5.13	5.50	1.13
<u>Appalachian</u>								
AC7 (raw)	64.29	7.92	9.71	5.38	6.18	2.41	2.31	1.89
AC6 (raw)	39.18	7.67	7.35	19.39	13.25	4.77	4.04	4.34

Table A9 (cont.)
Sieve Analysis

	PARTICLE TOP SIZE (WT%)				
	[-8]	[-35]	[-60]	[-100]	[-170] [-270]
<u>Western Canadian</u>					
WC9 (raw)	56.83	30.63	6.55	3.55	2.00 0.44
WC8 (raw)	61.23	13.38	10.70	7.45	5.56 1.68
WC9 (raw) (sample 1)	72.64	12.79	5.21	3.36	2.93 3.07
WC9 (raw) (sample 2)	70.54	10.43	7.37	6.19	4.08 1.38
WC9 (clean) (sample 1)	67.69	17.43	7.02	4.15	2.17 1.53
WC9 (clean) (sample 2)	65.95	16.98	7.70	5.56	2.93 0.88
<u>Appalachian</u>					
AC7 (raw)	66.00	15.36	7.03	5.04	3.87 2.70
AC6 (raw)	70.97	12.33	6.24	4.70	3.49 2.27

Table A9 (cont.)

Sieve Analysis

	<u>PARTICLE TOP SIZE (Wt%)</u>			
	<u>[-60]</u>	<u>[-100]</u>	<u>[-170]</u>	<u>[-270]</u>
<u>Western Canadian</u>				
WC9 (raw)	79.10	16.97	3.23	0.70
WC8 (raw)	28.73	54.63	15.90	0.75
WC7 (raw) (sample 1)	43.58	30.12	18.27	8.02
WC7 (raw)	46.60	37.00	10.19	6.20
WC7 (clean) (sample 1)	26.88	37.97	28.65	6.49
WC7 (clean) (sample 2)	41.81	36.49	19.53	2.17
<u>Appalachian</u>				
AC7 (raw)	30.52	56.75	11.55	1.18
AC6 (raw)	38.96	31.19	12.72	17.14

APPENDIX B

Data from Part II on [-8], [-35], [-60] and [-100] Samples

(See Table 2, Figure 2 in Text)

Table B1
Ruhr Dilatometry Measurements

WC5 Raw Coal [-100]

T	3°C/min			4.5°C/min		
T ₁	409	425.5	417.3	412	416	414
T ₂	448	449.5	448.8	453.5	453.5	453.5
T ₃	527	531	529	512	519	515.5
c	27.12	20.34	23.73	26.67	23.73	25.20
d	16.95	16.95	16.95	26.67	23.73	25.20
(c + d)	44.07	37.29	40.68	53.33	47.46	50.40
G	0.97	0.99	1.07	1.00	1.00	1.00

AC4 Raw Coal [-100]

T	3°C/min			4.5°C/min		
T ₁	376	392	384	376	399	387.5
T ₂	425	425	425	429	433	431
T ₃	525	511	518	502.5	505	503.8
c	17.24	12.28	14.76	20.34	18.33	19.34
d	91.38	105.26	98.32	115.25	131.67	123.46
(c + d)	108.62	117.54	113.08	135.59	150.00	142.80
G	1.13	1.11	1.12	1.11	1.10	1.11

Comparison of Ruhr Dilatometry under Standard and Non-Standard Test Conditions

Note: All P = 4300 psi (average in brackets)

Table P3
Gieseler Plastometry

Coal	Specific Gravity	Mesh	Heating Rate °C/min	Ts	Tfusion	Tfluid	Maximum Fluidity (ddpm)	T final	T solid
WC5	Raw	[-8x35]	3	442.2	449.3	471.7	45.3	483.0	495.5
			4	431.8	451.1	468.6	136.2	496.3	504.5
		[-35x60]	3	431.1	444.0	463.6	113.5	491.9	501.2
			4	452.8	459.8	480.6	226.8	508.0	517.9
		[-60]	3	434.5	452.5	467.0	38.4	484.2	503.6
			3	437.4	451.6	464.4	52.7	488.3	499.4
			Average	436.0	452.1	465.7	45.55	486.3	501.5
			4	425.2	439.7	475.2	160.9	500.1	513.5
			4	439.2	458.2	482.1	109.6	498.4	516.6
			Average	432.2	449.0	478.7	135.25	499.3	515.1
AC4	Raw	[-8x35]	3	410.7	418.8	452.2	7326.9	488.4	498.9
			3	406.6	418.3	473.2	8867.0	502.9	511.6
			Average	408.7	418.6	462.7	8096.95	495.7	505.3
			4	414.5	423.1	453.5	5867.5	504.0	509.1
		[-35x60]	3	397.4	411.7	455.8	3050.8	489.9	494.9
			4	403.8	420.5	463.4	4649.2	495.2	507.5
		[-60]	3	397.4	412.0	449.7	3281.8	485.6	499.7
			3	405.1	418.3	464.4	22819.3	493.5	499.7
			Average	401.3	415.2	457.1	13050.6	489.6	499.7
			4	392.0	411.9	454.9	5747.3	498.6	504.4
			4	406.4	423.0	469.9	7302.9	501.3	500.5
			Average	399.2	417.5	462.4	6525.1	499.95	502.5

Ts: initial softening temperature: T @ 1.0 ddpm (ALL IN °C)
 Tfusion: fusion temperature: T @ 5.0 ddpm
 Tfluid: maximum fluid temperature: T @ max. ddpm
 Tfinal: final temperature: T @ 1.0 ddpm
 Tsolid: solidification temperature: T @ 0.0 ddpm

Table B4

Free Swelling Index Measurements

Coal	MESM	FSI
WC5 (R/C)	$[-60]$ "	$7 \frac{1}{2}$ 8 Avg: 8
AC4 (R/C)	$[-60]$ "	8 $8 \frac{1}{2}$ Avg: $8 \frac{1}{2}$

Table P5

Sieve Analysis of Top Size Samples

Particle Top Size	WC5	AC4
A [-8] top size	wt. %	wt. %
[-8]	76.01	79.99
[-35]	11.34	10.12
[-60]	4.92	5.98
[-100]	4.39	2.08
[-170]	2.38	1.58
[-270]	0.953	0.24
R [-35] top size		
[-35]	68.65	34.89
[-60]	10.10	37.57
[-100]	9.69	15.68
[-170]	9.08	10.29
[-270]	2.48	1.56
C [-60] top size		
[-60]	97.13	94.53
[-100]	1.39	5.06
[-170]	1.32	0.27
[-270]	0.156	0.14

Table B6
Surface Area Measurements

Coal	MESH	Surface Area m ² /g
WC5 (R/C)	[-8]	0.133
	[-35]	0.617
	[-60]	1.248
AC4 (R/C)	[-8]	0.067
	[-35]	0.670
	[-60]	0.321

(by N₂ adsorption at liquid N₂ temperature)

APPENDIX C

Data From Part II on Float-Sink Fractions

(See Tables 2 and Figure 2 in Text)

Table C1
Ruhr Dilatometry Measurements

MC5 - Sink 1.6 x 1.42

At 4300 psi

MESH	[-8x35]						[-35x60]						[-60x100]					
	3°C/min			4.5° C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min		
	T	T ₁	T ₂	T ₃	c	d	(c+d)	G Factor										
	421	477	451	479	423	406	(414.5)	468	471	(470)	437	457	(447)	434	504	(469)	468	471
	471	459	471	(465)	438	522	(480)	-	-	-	471	522	(496.5)	507	504	(505.5)	-	-
	507	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3.125	0	(1.56)	4.69	3.13	(3.92)	3.25	9.38	(6.31)	0	0	5.50	3.42	(4.46)	12.7	1.7	(7.2)	0
	-3.125	1.587	(-0.77)	-4.69	-3.13	(-3.92)	-3.25	-9.38	(-6.31)	0	0	-5.50	-3.42	(-4.46)	-12.7	-1.7	(-7.2)	0
	0	1.587	0.79	4.69	3.13	(3.92)	3.25	9.38	(6.31)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table C1 cont'd
Ruhr Dilatometry Measurements
MC5 - Sink 1.42 x 1.32

MESH	[-8x35]										[-35x60]										[-60]										[-60x100]																			
	3°C/min					4.5°C/min					3°C/min					4.5°C/min					3°C/min					4.5°C/min					3°C/min					4.5°C/min														
	427	430	429	422	434	428	444 421	444 421	444 421	444 421	428	437	433	430	416	423	433	424	428.5	429	436	432.5	459	451	455	466	462	464	533 443	474 458	503 450	503	503	-	542	475	50.85	474	469	471.5	501	488.5	495	c	d	(c+d)	G Factor			
T ₁																																																		
T ₂																																																		
T ₃																																																		
c	6.4	6.35	(6.37)	8.33	7.94	(8.13)	13.31 8.62	8.33 14.29	(10.81) (11.45)	12.31	11.11	(11.70)	0	22.03	(11.02)	5.08	10.0	(7.54)	2.5	14.3	(8.35)																													
d	-6.4	-6.35	-6.37	-8.33	-7.94	-8.13	-13.31 -8.62	-8.33 -14.29	-10.81 -11.45	-12.31	-11.1	-11.7	3.48	1.69	(2.59)	-5.05	-10.0	(-7.54)	1.6	-14.3	-6.35																													
(c+d)	0	0	0	0	0	0	0	0	0	0	0	0	3.48	23.72	(13.61)	0	0	0	4.1	0	2.0																													
G Factor	0	0	0	0	0	0	0	0	0	0	0	0	1.1302	0.9463	(0.9462)	0	0	0	0.9833	0	0.66																													

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table C1 cont'd
Ruler Dilatometry Measurements

MC5 - Sink 1.32 x 1.22

MESH	[-80.25]				[-35.60]				[-40]				[-60d00]								
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min						
T																					
T ₁	408	424	(416)	394	414	(404)	412	415	(413.5)	405	-	407		408	414	(411)	417	434	(42.55)		
T ₂	433	436	(434.5)	437	437	(437)	447	444	(445.5)	444	-	440		430	433	(431.5)	434	446	(440)		
T ₃	472	518	(495)	467	507	(497)	477	486	(481.5)	477	481	(479)	476	511	(493.5)	469	505	(487)	489	(483)	
c	5.0	0	(2.5)	7.69	1.54	(4.62)	3.51	21.67	(12.59)	13.79	0	(6.9)	22.41	0	(11.21)	11.9	11.9	(11.9)	10.2	3.4	(6.8)
d	65.0	50.0	(57.5)	69.23	64.02	(76.42)	43.86	40.0	(41.93)	62.07	65.57	(63.82)	43.10	26.67	(34.89)	52.5	59.3	(55.9)	76.3	84.5	(80.4)
(c+d)	70.0	50.0	(60.0)	76.92	65.16	(81.54)	47.37	61.67	(54.52)	75.86	65.57	(70.72)	65.51	26.67	(46.1)	64.4	71.2	(67.8)	85.5	87.9	(87.2)
G Factor	L.0665	L.1108	(1.0864)	L.0922	L.1079	(1.1007)	L.0664	L.0240	(1.0426)	L.0548			L.0253			L.0459	L.0705	(1.0588)	L.0541	L.0882	(1.0564)

All test except [-40d00] used [-40] samples and compression at 4300 psi

() = mean

Table Q. cont'd
Ruhb D11atometry Measurements

MC5 - Float 122

MC54	[-80:35]						[-35:60]						[-60]						[-60:100]					
	3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min		
	T	T ₁	T ₂	T ₃	c	d	(c+d)	G	Factor															
	414	402	(408)	403	427	(415)	417 400	442 405	(429.5) (402.5)	408	385	(39.65)	415	418	(416.5)	411	430	(420.5)	425	425	(425)			
	440	437	(438.5)	437	441.5	(439)	451 441	548 445	(499.5) (443)	446	444	(445)	445	445	(445)	425	439	(432)	445	445	(445)			
	544	541	(542.5)	504	531	(517.5)	549	544	(546.5)	517	510	(513.5)	550	526	(538)	469	488	(478.5)	479	517	(498)			
	7.27	10.71	(8.99)	8.33	5.56	(6.94)	9.80 16.39	1.79 16.39	(5.79) (16.39)	11.86	11.48	(11.67)	22.0	18.97	(20.48)	11.3	0	(5.65)	5.4	5.2	(5.3)			
	47.27	44.69	(45.96)	51.67	70.37	(61.02)	9.80 24.59	1.79 24.59	(5.79) (24.59)	16.95	16.39	(16.67)	30.0	25.85	(27.93)	27.4	29.0	(28.2)	44.6	46.6	(45.6)			
	54.54	55.35	(54.95)	60.0	75.93	(67.96)	9.80 40.98	1.79 40.98	(5.79) (40.98)	28.88	27.87	(28.34)	52.0	44.83	(48.41)	38.7	29.0	(33.85)	50.0	51.8	(50.9)			
	1.1105	1.0993	(1.1052)	1.0875	1.1021	(1.0959)	1.0324	1.0302	(1.0313)	1.0213	1.0252	(1.0232)	1.0220	1.0179	(1.0200)	1.0282	1.0674	(1.0449)	1.0491	1.0847	(1.0668)			

All test except [-60d100] used [-60] samples and compression at 4300 psi

() = mean

Table C2
Ruler Dilatometry Measurements

AC4 - Size 1.6 x 1.42

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]			
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
T																
T ₁	405	400 (402.5)	400	427 (413.5)	436	436 (436)	424	420 (422)	393	399 (396)	418	430 (424)	438	430 (434)		
T ₂	420	428 (424)	435	447 (441)	453	464 (459)	452	460 (456)	434	436 (435)	447	462 (454.5)	442	446 (444)		
T ₃	544	486 (515)	486	497 (492)	-	-	-	-	462	555 (499)	-	-	462	474 (468)		
c	3.10	4.69 (3.89)	9.71	6.50 (8.11)	8.33	11.57 (9.95)	10.08	11.57 (10.83)	10.34	6.69 (8.52)	5.45	3.78 (4.61)	0	4.92 (2.46)		
d	1.55	3.13 (2.34)	4.85	4.88 (4.87)	-8.33	-11.57 (-9.95)	-10.08	-11.57 (-10.83)	5.17	5.02 (5.09)	-5.45	-3.78 (-4.61)	5.17	-4.92 (2.59)		
(c+d)	4.65	7.82 (6.23)	14.56	11.38 (12.98)	0	0	0	0	15.51	11.71 (13.61)	0	0	0	0 (5.05)		
G																
Factor	0.9534	0.9810 (0.9704)	0.9685	0.9893 (0.9786)					0.9734	0.9797 (0.9718)				1.0274	0	

All text except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruhr D1 Tactometry Measurements

ACA - 5114 1.42 x i. 32

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]			
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
	T ₁	T ₂	T ₃	c	d	(c+d)	G	Factor	T ₁	T ₂	T ₃	c	d	(c+d)	G	Factor
385	366	(376)	385	385	(385)	391	407	(399)	387	391	(389)	397	414	(405.5)	405	(410)
422	422	(422)	423	423	(423)	425	434	(430)	429	433	(431)	425	430	(427.5)	430	(432)
469	474	(472)	522	479	(501)	531	465	(498)	507	507	(507)	511	522	(517)	485	(469)
7.69	12.17	(9.95)	9.50	9.52	(9.41)	14.75	15.25	(15.0)	17.54	16.39	(16.97)	23.14	22.05	(22.59)	15.87	18.64
64.82	80.0	(72.30)	8.06	104.8	(92.7)	36.07	37.29	(36.68)	57.89	60.66	(59.28)	76.03	89.76	(82.90)	30.16	54.24
72.3	92.17	(82.23)	89.9	114.32	(102.11)	50.82	52.54	(51.68)	75.43	77.05	(76.25)	99.17	111.80	(105.49)	46.03	72.88
1.0828	1.1045	(1.0939)	1.1348	1.0984	(1.1183)	1.0660	1.0287	(1.0465)	1.0774	1.0802	(1.0788)	1.0803	1.0952	(1.0879)	1.0494	1.0336

All test except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruhr D11atometry Measurements
AC4 - Sink 1.32 x 1.22

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]			
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
T																
T ₁	404	378 (391)	369	411 (390)	379	-	391	-	367	381 (374)	386	392	386	392 (369)	399	381 (390)
T ₂	413	407 (410)	408	415 (411.5)	415	-	410	-	415	421 (418)	406	414	406	414 (410)	411	415 (413)
T ₃	506	478 (492)	494	481 (482.5)	471	515 (493)	498	524 (511)	547	534 (540.5)	480	477	480	477 (478.5)	480	484 (482)
c	3.23	12.7 (7.96)	7.94	1.59 (4.76)	13.56	0 (6.78)	3.39	0 (1.69)	18.64	16.95 (17.8)	20.34	23.21	20.34	23.21 (21.78)	1.69	23.21 (12.45)
d	240.32	257.14 (248.73)	257.14	288.89 (273.01)	198.31	155.17 (176.74)	140.68	147.46 (144.07)	15.598	201.69 (178.81)	205.08	232.14	205.08	232.14 (218.61)	238.98	276.19 (257.88)
(c+d)	243.55	269.84 (256.69)	265.08	290.48 (277.77)	211.87	155.17 (183.44)	144.07	147.46 (145.76)	174.57	218.64 (195.61)	225.42	255.35	225.42	255.35 (240.39)	240.67	300.0 (270.33)
G	1.1225	1.1104 (1.1202)	1.1461	1.0841 (1.1141)	1.1042		1.1295		1.1833	1.1645 (1.1752)	1.0976	1.0870	1.0976	1.0870 (1.0923)	1.1045	1.1119 (1.1059)

All test except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruhr Dilatometry Measurements

AC4 - Float 1.22

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]				
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		
T																	
T ₁	376	-	370	381	(375.5)	365	-	380	377	(378.5)	370	370	370	(370)	372	-	
T ₂	400	-		410	(411)	409	-		416	(416)	416	410	410	(413)	407	-	
T ₃	474	520	(497)	483	(483)	469	469	(469)	498	(492)	487	501	(494)	472	472	(472)	
c	4.76	0	(2.38)	16.13	6.45	(11.29)	18.97	0	(9.48)	11.86	18.64	(15.25)	16.95	13.33	(15.14)	22.95	0
d	219.05	254.04	(236.94)	251.67	283.87	(267.74)	191.38	200.0	(195.69)	223.73	261.02	(242.37)	213.56	195.0	(204.28)	157.38	175.41
(c+d)	223.81	254.04	(239.32)	267.74	290.32	(279.03)	210.35	200.0	(205.17)	235.59	279.66	(257.62)	230.51	208.33	(219.42)	180.33	175.41
G	Factor	1.1241		1.1319	1.1272	(1.1301)	1.1138			1.1375	1.1229	(1.1299)	1.1318	1.1500	(1.1412)	1.0969	
																1.0982	1.0989

All text except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C3
Free Swelling Index Measurements

Coal	Mesh	FRACTION					
		R/C	1.6 Sink	1.6x1.42 Sink	1.42x1.32 Sink	1.32x1.22 Sink	1.22 Float
WC5	[-8x35]		7, 7, 7 (7)	1, 1 ¹ / ₂ , 1 ¹ / ₂ (1 ¹ / ₂)	7 ¹ / ₂ , 7 ¹ / ₂ , 7 ¹ / ₂ (3 ¹ / ₂)	9, 9, 9 (9)	6, 6, 6 (6)
AC4	[-8x35]		8, 8 ¹ / ₂ , 8 (8)	1, 1 ¹ / ₂ , 1 (1)	7 ¹ / ₂ , 7 ¹ / ₂ , 7 ¹ / ₂ (3 ¹ / ₂)	8 ¹ / ₂ , 8 ¹ / ₂ , 8 (8 ¹ / ₂)	8 ¹ / ₂ , 9, 8 ¹ / ₂ (8 ¹ / ₂)
WC5	[-35x60]	7, 6, 6 ¹ / ₂ (6 ¹ / ₂)		1 ¹ / ₂ , 1 ¹ / ₂ (1 ¹ / ₂)	2 ¹ / ₂ , 2 ¹ / ₂ (2 ¹ / ₂)	8, 7 ¹ / ₂ (8)	7 ¹ / ₂ , 7 (7)
AC4	[-35x60]	4, 4 ¹ / ₂ , 5 (4 ¹ / ₂)		1, 1 (1)	4, 4 ¹ / ₂ (4)	8 ¹ / ₂ , 8 ¹ / ₂ (8 ¹ / ₂)	8 ¹ / ₂ , 9 (9)
WC5	[-60]	8, 8 (8)		1 ¹ / ₂ , 1 ¹ / ₂ (1 ¹ / ₂)	8, 7 ¹ / ₂ (8)	8 ¹ / ₂ , 9 (9)	5 ¹ / ₂ , 6 (6)
AC4	[-60]	8, 8 ¹ / ₂ (8)		4, 4 (4)	8, 7 ¹ / ₂ (8)	8, 8 ¹ / ₂ (8)	8 ¹ / ₂ , 8 (8)

Table C4
Proximate Analysis of Sink-Float Sample

Coal Fraction	Mesh of Original Shape	ANALYSIS db%			
		Moisture	Ash	Volatile Matter	Fixed Carbon
WC5 (R/C)	[-60]	0.33	8.44	23.20	68.6
WC5 (R/C)	[-8x35]	0.30	8.38	ND	ND
WC5 1.6 Sink	[-60]	0.51	12.8	23.3	63.8
WC5 1.6 Sink	[-35x60]	0.39	32.9	18.5	48.6
WC5 1.6 Sink	[-8x35]	0.27	35.4	18.1	46.5
WC5 1.6x1.42 Sink	[-60]	0.43	36.5	16.8	46.7
WC5 1.42x1.32 Sink	[-60]	0.41	8.20	22.4	69.4
WC5 1.32x1.22 Sink	[-60]	0.19	4.44	24.0	71.6
WC5 1.22 Float	[-60]	0.19	3.71	23.4	72.9
AC4 (R/C)	[-60]	0.31	18.0	23.4	58.5
AC4 (R/C)	[-8x35]	0.23	15.5	ND	ND
AC4 Sink 1.6	[-60]	0.23	22.8	21.7	54.5
AC4 Sink 1.6	[-8x35]	0.30	66.4	12.2	21.4
AC4 Sink 1.6	[-35x60]	0.22	39.4	18.6	42.0
AC4 1.6x1.42 Sink	[-60]	0.40	40.7	19.3	40.0
AC4 1.42x1.32 Sink	[-60]	0.32	43.1	22.6	34.3
AC4 1.32x1.22 Sink	[-60]	0.38	9.60	25.8	64.6
AC4 1.22 Float	[-60]	0.33	8.53	25.1	66.4

Table C5

Ultimate Analysis on Float-Sink Samples of [-35x60] Fraction

Coal	WC5				AC4			
	Sink 1.6x1.42	Sink 1.42x1.32	Sink 1.32x1.22	Float 1.22	Sink 1.6x1.42	Sink 1.42x1.32	Sink 1.32x1.22	Float 1.22
Fraction								
C (%) db	65.35	77.45	82.78	82.80	62.42	78.56	80.52	84.15
H (%)	3.50	4.07	4.48	4.38	3.50	5.63	4.51	4.67
N (%)	0.42	7.43	0.69	0.73	0.83	3.21	1.23	1.25
S (%)	0.51	0.50	1.07	0.20	1.68	0.97	0.82	0.89
O (%)	5.69	3.59	6.54	3.98	*	*	5.12	3.62
Ash (%)	24.53	13.61	4.44	7.90	37.15	30.47	7.80	5.42

*Measurement or calculational error results in negative 0%

Table C6
Maceral Analysis of Sink-Float Sample

COAL: ACA [-8x35] mesh

SP. GR.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float	[-8x35] out of [-8] R/C
Ash %db	40.56	42.98	9.57	8.50	15.48
S %db	1.68	0.97	0.82	0.90	0.98
M.M. Coeff.	0.72	0.71	0.94	0.95	0.91
Vit.	26.3	32.7	56.8	58.0	59.5
Exin.	5.6	6.5	2.7	5.8	2.9
S.F.	27.2	16.6	12.3	12.5	11.9
F.	5.0	3.8	2.7	3.4	2.8
Mic.	8.3	11.2	19.9	15.4	13.8
M.M.	27.6	29.2	5.6	4.9	9.0
Random Ro	1.05	1.05	1.05	1.06	1.06
Maximum Ro	1.11	1.11	1.11	1.12	1.12

COAL: WCS [-8x35] mesh

Ash %db	36.32	8.17	4.43	3.70	8.35
S %db	0.51	0.50	1.07	0.20	0.75
M.M. Coeff.	0.76	0.95	0.97	0.98	0.95
Vit.	20.2	42.9	69.5	79.3	63.6
Exin.	-	1.9	22.2	-	-
S.F.	44.9	39.9	8	12.8	21.9
F.	9.6	6.1	4.5	1.8	4.0
Mic.	1.8	4.6	2.9	4.1	5.7
M.M.	23.5	4.6	2.0	2.0	4.8
Random Ro	1.06	1.05	1.05	1.06	1.08
Maximum Ro	1.12	1.11	1.11	1.12	1.14

Table C6
Maceral Analysis of Float-Sink Sample

COAL: AC4 [-35x60] mesh

sp.gr.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float
Ash	37.04	30.38	7.77	5.40
S	1.68	0.97	0.82	0.89
M.N. Coeff.	0.75	0.81	0.96	0.97
Vit.	35.1	40.3	59.5	62.3
Exin.	2.0	3.6	2.8	1.6
S.F.	27.1	20.4	20.0	13.8
F.	5.1	5.7	4.2	7.2
Mic.	5.7	11.0	9.4	12.2
M.N.	25.0	19.0	4.1	2.9
Random Ro	1.05	1.05	1.05	1.06
Maximum Ro	1.11	1.11	1.11	1.11

COAL: MC5 [-35x60] mesh

Ash	24.42	13.55	4.15	7.89	12.01
S	0.51	0.50	1.07	0.21	0.21
M.N. Coeff.	0.85	0.922	0.975	0.956	0.93
Vit.	34.0	44.0	56.9	64.8	50.0
Exin.	0	7	1.6	4	4
S.F.	37.9	35.7	22.8	19.7	29.1
F.	10.2	4.6	10.7	4.8	12.0
Mic.	2.9	7.0	5.5	5.9	1.8
M.N.	15.0	8.0	2.5	4.4	6.7
Random Ro	1.06	1.05	1.05	1.06	
Maximum Ro	1.12	1.11	1.11	1.12	

Table C7
Microlithotype Analysis of Float Sink Fractions

COAL: WC5 [-8x35]						
	1.6 x 1.4 sq	1.42 x 1.32 sq	1.32 x 1.22 sq	1.22 sq	R/C	R/C [-8x35]
Liptite	-	1	-	-	-	-
Clarite	-	22	43	80	20	35
Vitrite	8	39	41	17	51	29
Vitrinerite	32	27	12	2	21	28
Inertite	58	(10)	(7)	(2)	(9)	(11)
SF	(-)	(2)	(1)	(2)	(8)	(4)
F	(-)	(3)	(-)	(-)	(2)	(2)
M	2	11	4	1	7	8
Trinacrite	-	-	-	-	-	-
Durite	-	-	-	-	-	-
Total	100	100	100	100	100	100

COAL: AC4 [-8x35]						
	1.6 x 1.4 sq	1.42 x 1.32 sq	1.32 x 1.22 sq	1.22 sq	R/C	R/C [-8x35]
Liptite	-	2	-	-	-	-
Clarite	1	34	38	72	24	32
Vitrite	27	34	43	10	30	24
Vitrinerite	33	27	14	15	20	30
Inertite	32	(3)	(4)	(5)	(3)	(12)
SF	(3)	(1)	(-)	(1)	(6)	(6)
F	(2)	(3)	(4)	(1)	(4)	(5)
M	(3)	3	3	2	16	11
Trinacrite	5	-	-	-	7	1
Durite	2	-	-	-	-	-
Total	100	100	100	100	100	100

Table C8
Sieve Analysis of Float-Sink Samples

		Weight%										
Sample	Mesh Size	-8	-10	-18	-20	-28	-32		-60	-100	-170	-270
WC5 [-8/35]												
1.6x1.42 sink		11.2	33.3	11.1	19.2	12.3	12.9					
1.42x1.32 sink		15.0	40.0	9.1	18.9	8.0	9.0					
1.32x1.22 sink		14.1	34.6	10.7	23.9	8.0	8.8					
1.22 float		8.3	31.3	10.5	26.9	12.1	10.2					
Raw Coal		38.4	35.1	8.0	11.8	4.2	2.5					
WC5 [-60]												
1.6x1.42 sink												
1.42x1.32 sink									21.52	69.36	8.15	0.97
1.32x1.22 sink									88.19	10.02	1.44	0.35
1.22 Float									77.4	15.99	5.53	1.09
AC4 [-8/35]												
Raw Coal		25.9	37.3	10.5	14.6	6.2	5.5					
AC4 [-60]												
1.6x1.42 sink												
1.42x1.32 sink									42.38	3.45	49.97	4.20
1.32x1.22 sink									72.71	22.87	3.78	0.64
1.22 Float									69.69	25.73	4.02	0.56

Table C9
Surface Area Measurements - m^2/g

SAMPLE	WC5						AC4			
	Raw Coal	Sink 1.42x1.6	Sink 1.32x1.42	Sink 1.22x1.32	Float 1.22	Raw Coal	Sink 1.42x6	Sink 1.32x1.42	Sink 1.22x1.32	Float 1.22
[-8x35]	0.504	0.256	1.621	9.196	0.012	0.051	1.643	0.074	0.047	0.047
[-35x60]	0.597	0.382	0.842	0.892	0.190	0.005	0.833	0.088	0.117	0.102
[-60]	1.248	0.989	1.608	0.670	0.390	0.321	0.289	0.075	0.583	0.790
[-8]	0.133	-	-	-	-	0.067	-	-	-	-
[-35]	0.617	-	-	-	-	0.670	-	-	-	-

(by N_2 adsorption of Ltg. N_2 temperature)

Table C10
Gieseler Plastometry Under Standard and Non-Standard Test Conditions

COAL	Specific Gravity	Mesh	Heating Rate °C/min	Ts	Tfusion	Tfluid	Maximum Fluidity (ddpm)	T final	T solid
WC5	Raw	[-8x35]	3	442.2	449.3	471.7	45.3	483.0	495.5
			4	431.8	451.1	468.6	136.2	496.3	504.5
		[-35x60]	3	431.1	444.0	463.6	113.5	491.9	501.2
			4	452.8	459.8	480.6	226.8	508.0	517.9
		[-60]	3	434.5	452.5	467.0	38.4	484.2	503.6
			3	437.4	451.6	464.4	52.7	488.3	499.4
				(436.0)	452.1)	(465.7)	455.5)	(486.3)	(501.5)
			4	425.2	439.7	475.2	160.9	500.1	513.5
			4	439.2	458.2	482.1	109.6	498.4	516.6
				(432.2)	(449.0)	(478.7)	(135.25)	(499.3)	(515.1)
	Sink 1.6x1.42	[-8x35]	3	-	-	-	0.0	-	-
			4	-	-	423.0	0.1	-	425.0
		[-35x60]	3	446.7	-	457.3	1.5	472.2	491.7
			3	-	-	455.9	0.7	-	491.5
		[-60]	4	460.0	-	477.6	2.2	478.6	506.6
			3	465.7	-	465.7	1.0	465.7	502.8
			4	-	-	463.2	0.8	-	504.6
	Sink 1.42x1.32	[-8x35]	3	-	-	-	0.0	-	-
			4	-	-	453.8	0.1	-	457.6
		[-35x60]	3	446.9	-	452.8	2.5	473.3	489.7
			3	439.9	-	456.0	1.7	465.5	489.9
			4	443.8	-	469.3	4.5	484.4	502.4

Ts: initial softening temperature: T @ 1.0 ddpm (ALL in °C)
 Tfusion: fusion temperature: T @ 5.0 ddpm
 Tfluid: maximum fluid temperature: T @ max. ddpm
 Tfinal: final temperature: T @ 1.0 ddpm
 Tsolid: solidification temperature: T @ 0.0 ddpm

Table C10 cont'd
Gieseler Plastometry Under Standard and Non-Standard Test Conditions

COAL	Specific Gravity	Mesh	Heating Rate °C/min	T _s	T _{fusion}	T _{fluid}	Maximum Fluidity (ddpm)	T final	T solid
WC5	Raw	[-35]	3	432.8	447.3	470.9	63.5	488.7	505.5
			3	432.4 (432.6)	447.5 (447.4)	471.2 (471.1)	103.8 (83.7)	491.8 (490.3)	500.6 (503.1)
			4	433.9	448.0	479.3	146.7	484.0	487.1
			4	433.4 (433.7)	448.6 (448.3)	478.5 (478.9)	197.5 (172.1)	492.8 (488.4)	483.7 (485.4)
			3	434.5	452.5	467.0	38.4	484.2	503.6
			3	437.4 (436.0)	451.6 (452.1)	464.4 (465.7)	52.7 (45.55)	488.3 (486.3)	499.4 (501.5)
		[-60]	4	425.2	439.7	475.2	160.9	500.1	513.5
			4	439.2 (432.2)	458.2 (449.0)	482.1 (478.7)	109.6 (135.25)	498.4 (499.3)	516.6 (515.1)
			3	403.2	416.1	462.0	2858.2	498.4	505.9
			3	410.5 (406.9)	423.5 (419.8)	452.8 (457.4)	3832.2 (3345.2)	497.8 (498.1)	503.7 (504.8)
			4	409.0	419.8	464.7	4313.3	506.7	511.4
			4	410.2 (409.6)	425.8 (422.8)	462.2 (463.5)	4600.9 (4457.1)	506.5 (506.6)	514.3 (512.9)
AC4	Raw	[-35]	3	397.4	412.0	449.7	3281.8	485.6	499.7
			3	405.1 (401.3)	418.3 (415.2)	464.4 (457.1)	22819.3 (13050.55)	493.5 (489.6)	499.7 (499.7)
			4	392.0	411.9	454.9	5747.3	498.6	504.4
			4	406.4 (399.2)	423.0 (417.5)	469.9 (462.4)	7302.9 (6525.1)	501.3 (499.95)	500.5 (502.5)
		[-60]	3	397.4	412.0	449.7	3281.8	485.6	499.7
			3	405.1 (401.3)	418.3 (415.2)	464.4 (457.1)	22819.3 (13050.55)	493.5 (489.6)	499.7 (499.7)
			4	392.0	411.9	454.9	5747.3	498.6	504.4
			4	406.4 (399.2)	423.0 (417.5)	469.9 (462.4)	7302.9 (6525.1)	501.3 (499.95)	500.5 (502.5)

T_s: initial softening temperature: T @ 1.0 ddpm (ALL in °C)
 T_{fusion}: fusion temperature: T @ 5.0 ddpm
 T_{fluid}: maximum fluid temperature: T @ max. ddpm
 T_{final}: final temperature: T @ 1.0 ddpm
 T_{solid}: solidification temperature: T @ 0.0 ddpm

Table C10 cont'd
Gieseler Plastometry Under Standard and Non-Standard Test Conditions

COAL	Specific Gravity	Mesh	Heating Rate °C/min	T _s	T _{fusion}	T _{fluid}	Maximum Fluidity (ddpm)	T _{final}	T _{solid}
WC5	Sink 1.32x1.22	[-60]	3	446.4	-	458.0	1.7	469.3	486.0
			4	450.3	-	469.7	2.7	482.9	503.9
		[-8x35]	3	444.3	-	457.5	4.7	461.0	480.2
			4	-	-	-	0.0	-	-
	Sink 1.32x1.22	[-35x60]	3	421.9	443.9	476.1	112.1	497.4	506.5
			3	431.0	445.7	469.7	124.1 (118.05)	495.5	505.1
		[-60]	4	437.5	455.6	480.5	164.3	510.5	519.8
			3	422.9	437.9	464.1	70.3	485.2	502.2
	Float 1.22	[-60]	4	431.3	449.5	479.9	134.9	491.8	512.9
			3	448.6	457.5	465.2	17.4	480.0	506.5
		[-8x35]	4	-	-	0.0	-	-	-
			3	437.7	452.6	462.1	11.0	478.2	497.9
		[-35x60]	3	436.2	455.0	461.3	7.4 (9.2)	478.6	495.9
			4	447.6	470.9	482.4	14.1	501.8	514.1
		[-60]	3	442.5	459.8	467.7	9.3	484.7	502.1
			4	432.3	449.2	472.3	23.7	494.8	507.6
	Raw	[-8x35]	3	410.7	418.8	452.2	7326.9	488.4	498.9
			3	406.6 (408.7)	418.3 (418.6)	473.2 (462.7)	8867.0 (8096.95)	502.9 (495.7)	511.6 (505.3)

T_s: initial softening temperature: T @ 1.0 ddpm (ALL in °C)
 T_{fusion}: fusion temperature: T @ 5.0 ddpm
 T_{fluid}: maximum fluid temperature: T @ max. ddpm
 T_{final}: final temperature: T @ 1.0 ddpm
 T_{solid}: solidification temperature: T @ 0.0 ddpm

Table C10 cont'd
Gieseler Plastometry Under Standard and Non-Standard Test Conditions

COAL	Specific Gravity	Mesh	Heating Rate °C/min	T _s	T _{fusion}	T _{fluid}	Maximum Fluidity (ddpm)	T final	T solid
AC4 cont	Sink 1.6x1.42	[-35x60]	4	414.5	423.1	453.5	5867.5	504.0	509.1
			3	397.4	411.7	455.8	3050.8	489.9	494.9
			4	403.8	420.5	463.4	4649.2	495.2	507.5
		[-60]	3	397.4	412.0	449.7	3281.8	485.6	499.7
			3	405.1 (401.3)	418.3 (415.2)	464.4 (457.1)	22819.3 (13050.6)	493.5 (489.6)	499.7 (499.7)
			4	392.0	411.9	454.9	5747.3	498.6	504.4
		[-8x35]	4	406.4 (399.2)	423.0 (417.5)	469.9 (462.4)	7302.9 (6525.1)	501.3 (499.95)	500.5 (502.5)
			3	410.3	427.2	510.2	30962.0	-	-
			4	415.9	431.5	525.5	31021.8	-	-
		[-35x60]	3	424.4	435.1	463.1	20813.1	475.5	486.1
			3	419.0	429.9	489.4	31240.8	-	-
			3	430.3	444.2	465.9	307.7 (17453.9)	497.4	499.9
	Sink 1.6x1.42	[-35x60]	4	437.9	453.5	489.7	15258.9	497.3	505.0
		[-60]	3	420.5	434.5	492.5	30961.5	-	-
			4	431.6	450.4	469.6	5555.7	513.2	525.7
	Sink 1.42x1.32	[-8x35]	3	404.9	414.08	449.5	15866.5	492.64	499.7
			4	415.08	429.76	470.7	9863.1	515.2	527.0
		[-35x60]	3	405.8	422.4	448.5	23045.3	492.4	503.6
			3	-	-	448.6	22284.0	-	-
			3	409.5	422.6	478.3	31228.9 (25519.4)	-	-

T_s: initial softening temperature: T @ 1.0 ddpm (ALL in °C)
 T_{fusion}: fusion temperature: T @ 5.0 ddpm
 T_{fluid}: maximum fluid temperature: T @ max. ddpm
 T_{final}: final temperature: T @ 1.0 ddpm
 T_{solid}: solidification temperature: T @ 0.0 ddpm

Table C10 cont'd
Gieseler Plastometry Under Standard and Non-Standard Test Conditions

COAL	Specific Gravity	Mesh	Heating Rate °C/min	Ts	Tfusion	Tfluid	Maximum Fluidity (ddpm)	T final	T solid
AC4	Sink 1.32x.122	[-60]	4	417.8	430.7	453.9	18699.1	504.1	514.1
			3	405.2	425.2	452.1	30507.5	467.7	468.8
			4	407.5	429.6	454.9	17708.2	509.4	506.4
		[-8x35]	3	397.75	408.3	462.4	6826.0	500.2	510.1
			4	400.4	412.9	465.4	9410.3	497.7	502.6
		[-35x60]	3	399.1	416.3	461.3	5667.6	500.4	506.7
			3	399.7	413.6	456.0	18344.2 (12005.9)	497.5	509.0
		[-60]	4	404.9	423.4	464.5	14570.8	505.5	497.4
			3	399.2	414.8	462.8	7162.8	496.9	505.9
			4	401.5	420.4	481.2	28952.1	513.1	532.3
	Float 1.22	[-8x35]	3	413.9	420.3	461.5	4212.2	503.8	512.1
			4	406.2	420.3	469.3	7051.5	512.0	513.7
		[-35x60]	3	398.6	416.4	449.8	4966.6	491.6	502.8
			3	398.8	419.1	459.5	4692.1 (4829.35)	496.3	498.7
		[-60]	4	400.7	415.5	472.1	10369.8	480.4	496.6
			3	400.5	417.2	450.8	20477.5	503.1	515.1
			4	396.95	415.0	457.1	12362.6	509.6	513.1

Ts: initial softening temperature: T @ 1.0 ddpm (ALL in °C)
 Tfusion: fusion temperature: T @ 5.0 ddpm
 Tfluid: maximum fluid temperature: T @ max. ddpm
 Tfinal: final temperature: T @ 1.0 ddpm
 Tsolid: solidification temperature: T @ 0.0 ddpm

APPENDIX D

Raw Data from Part II on Blends

Table D1
Blend Measurements

Blend	1	2	3	4	5	6	7
<u>Maceral Analysis</u>							
Vitrinite	50						
Exinite	4.0						
Semi fusinite	29.1						
Fusinite	12.0						
Micrinite	1.8						
Mineral Matter	6.7						
<u>Proximate Analysis</u>							
Ash % db	11.1		12.71	6.2	4.8	6.1	9.1
<u>Pheology</u>							
Contraction %	8.73		8.65	10.03	16.25	10.83	17.8
Dilation %	103.51		0	207.42	30.74	24.17	174.0
Total Dilation %	112.24		8.65	217.45	46.99	35.00	191.8
Maximum Fluidity ddpm	738.8						
FSI	4 ¹ / ₂ , 5, 5(5)		4, 4 ¹ / ₂ , 4 ¹ / ₂ , (4 ¹ / ₂)	8, 7 ¹ / ₂ , 8(8)	8, 8 ¹ / ₂ , 9 (8 ¹ / ₂)	7, 7, 7 ¹ / ₂ (7)	7 ¹ / ₂ , 8, 8, (8)
Surface Area m ² /g		0.400					

Table D7
Maceral Analysis of Sink-Float Sample

COAL: AC4 [-35x60] mesh

sp.gr.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float
Ash	37.04	30.38	7.77	5.40
S	1.68	0.97	0.82	0.89
M.M. Coeff.	0.75	0.81	0.96	0.97
Vit.	(468) 351	(498) 403	(620) 595	(642) 623
Exin.	(26) 20	(44) 36	(30) 28	(16) 16
S.F.	(362) 271	(252) 204	(208) 200	(142) 138
F.	(68) 51	(70) 57	(44) 42	(74) 72
Mic.	(76) 57	(136) 110	(98) 94	(126) 122
M.M.	250	190	41	29
Random Ro	1.05	1.05	1.05	1.06
Maximum Ro	1.11	1.11	1.11	1.11

COAL: WC5 [-35x60] mesh

Ash	24.42	13.55	4.15	7.89	12.01
S	0.51	0.50	1.07	0.21	0.21
M.M. Coeff.	0.85	0.922	0.975	0.956	0.93
Vit.	(400) 340	(478) 440	(584) 569	(678) 648	(537) 500
Exin.	-	(8) 7	(16) 16	(4) 4	(4) 4
S.F.	(446) 379	(388) 357	(234) 228	(206) 197	(313) 291
F.	(120) 102	(50) 46	(110) 107	(50) 48	(129) 120
Mic.	(34) 29	(76) 70	(56) 55	(62) 59	(19) 18
M.M.	150	80	25	44	67
Random Ro	1.06	1.05	1.05	1.06	
Maximum Ro	1.12	1.11	1.11	1.12	

() = mineral matter free values.

Table D7 cont'd
Maceral Analysis of Sink-Float Sample

COAL: AC4 [-8x35] mesh

sp.gr.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float	[-8x35] out of [-8] R/C
Ash %db	40.56	42.98	9.57	8.50	15.48
S %db	1.68	0.97	0.82	0.90	0.98
M.M. Coeff.	0.72	0.71	0.94	0.95	0.91
Vit.	263	327	568	580	595
Exin.	56	65	27	58	29
S.F.	272	166	123	125	119
F.	50	38	27	34	28
Mic.	83	112	199	154	138
M.M.	276	292	56	49	90
Random Ro	1.05	1.05	1.05	1.06	1.06
Maximum Ro	1.11	1.11	1.11	1.12	1.12

COAL: WC5 [-8x35] mesh

Ash %db	36.32	8.17	4.43	3.70	8.35
S %db	0.51	0.50	1.07	0.20	0.75
M.M. Coeff.	0.76	0.95	0.97	0.98	0.95
Vit.	202	429	695	793	636
Exin.	-	19	2	-	-
S.F.	449	399	221	128	219
F.	96	61	8	18	40
Mic.	18	46	45	41	57
M.M.	235	46	29	20	48
Random Ro	1.06	1.05	1.05	1.06	1.08
Maximum Ro	1.12	1.11	1.11	1.12	1.14

() = mineral matter free values.

Table D8
Micro lithotype Analysis of Sink Float Fractions
 (65%)

COAL: WC5 [-8x35]

	1.6 x 1.4 sq	1.42 x 1.32 sq	1.32 x 1.22 sq	1.22 sq	R/C	R/C [-8x35]
Liptite	-	-	-	-	-	-
Clarite	-	1	-	-	1	-
Vitrate	8	22	43	80	20	35
Vitrinite	32	39	41	17	51	29
Inertinite	58	27	12	2	21	28
SF	-	10	7	2	9	11
F	-	2	1	2	8	4
M	-	3	-	-	2	2
Trimacerite	2	11	4	1	7	8
Durite	-	-	-	-	-	-
Total	100	100	100	100	100	100

COAL: AC4 [-8x35]

Liptite	-	-	-	-	-	-
Clarite	1	2	2	1	3	2
Vitrinite	33	34	43	10	30	24
Inertinite	32	27	14	15	20	30
SF	3	3	4	5	3	12
F	2	1	-	1	6	6
M	3	3	4	1	4	5
Trimacerite	5	3	3	2	16	11
Durite	2	-	-	-	7	1
Total	100	100	100	100	100	100

APPENDIX E

Print Out from Computer Blending Program

REC # RUN NAME

```
1  OPTION 3.1;  
2  MINIMIZE MISFIT:4+0X+0Y+0Z;  
3  SUBJECT TO  
4  P1:20.3X+32.7X+50.8Y+58.0Z-M<63.0;  
5  Q1:20.3X+32.7X+50.8Y+58.0Z+M>63.0;  
6  P2:0.97X+1.97X+4.62Y+4.64Z-M<2.9;  
7  Q2:0.97X+1.97X+4.62Y+4.64Z+M>2.9;  
8  P3:40.0W+43X+9.6Y+8.5Z-M<9.3;  
9  Q3:40.0W+43X+9.6Y+8.5Z+M>9.3;  
10 SI:V+X+Y+Z=1;
```

MODEL SUMMARY

THE LINEAR PROGRAMMING PROBLEM IS TO
MINIMIZE MISFIT.

THERE ARE

5 ACTIVITY VARIABLES.

7 CONSTRAINT(S)

(3 OF TYPE LF, 1 OF TYPE EQ, 3 OF TYPE GE).

0 LXPRESSION(S) TO BE EVALUATED.

10 VARIABLE(S) ADDED TO THE MODEL

(3 SLACK, 3 SURPLUS, 4 ARTIFICIAL).

OPTIONS SUMMARY

1.1 (DEFAULT)

SHOW MODEL ONLY

2.0 (DEFAULT)

DO NOT SCALE OBJECTIVE FUNCTION

3.1 (SELECTED)

DISPLAY BASIC VARIABLES AT EACH ITERATION

4.0 (DEFAULT)

OBJECTIVE FUNCTION EQUATION IS $-2+(X1+X2+....) = -VALUE$

THE MODEL REQUIRES 3712 OF THE 747536 BYTES OF STORAGE AVAILABLE.

OPTION 1.1 - SHOW MODEL ONLY

ROW NAME	ACTIVITY VARIABLES				
	M	W	X	Y	Z
MISFIT	1.000	0.	0.	0.	0.
P1	-1.000	26.300	32.700	56.800	53.000
Q1	1.000	26.300	32.700	56.800	58.000
P2	-1.000	.970	1.970	4.620	4.640
Q2	1.000	.970	1.970	4.620	4.640
P3	-1.000	40.600	43.000	9.600	8.500
Q3	1.000	40.600	43.000	9.600	8.500
S1	0.	1.000	1.000	1.000	1.000

(CONTINUED...)

ROW NAME	TYPE	RHS
MISFIT	MIN	0.
P1	LE	63.600
Q1	GE	63.600
P2	LE	2.900
Q2	GE	2.900
P3	LE	8.300
Q3	GE	8.300
S1	EQ	1.000

OPTION 2.0 - DO NOT SCALE OBJECTIVE FUNCTION

RIGHT-HAND SIDE HAS BEEN DIVIDED BY 10.000

OPTION 3.1 - DISPLAY BASIC VARIABLES AT EACH ITERATION

SOLUTION # 00001 (INFEASIBLE): PHASE 1 SUM = 75.800									
VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	
P1	SLAK	63.600	P2	SLAK	2.900	P3	SLAK	8.300	
Q1	ARTF	63.600	Q2	ARTF	2.900	Q3	ARTF	8.300	
S1	ARTF	1.000							

SOLUTION # 00002 (INFEASIBLE): PHASE 1 SUM = 60.514									
X ACTV WAS INTRODUCED AND P3 SLAK WAS REMOVED, RESULTING IN									
VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	
X	ACTV	.193	P1	SLAK	57.288	P2	SLAK	2.519	
Q1	ARTF	57.288	Q2	ARTF	2.519	Q3	ARTF	0.	
S1	ARTF	.506							

SOLUTION # 00003 (INFEASIBLE): PHASE 1 SUM = 27.068									
Z ACTV WAS INTRODUCED AND P2 SLAK WAS REMOVED, RESULTING IN									
VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	
X	ACTV	0.075	Z	ACTV	.592	P1	SLAK	26.737	
Q1	ARTF	26.737	Q2	ARTF	0.	Q3	ARTF	0.	
S1	ARTF	.331							

SOLUTION # 00004 (INFEASIBLE): PHASE 1 SUM = 27.068									
W ACTV WAS INTRODUCED AND Q2 ARTF WAS REMOVED, RESULTING IN									
VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	
M	ACTV	0.	X	ACTV	0.075	Z	ACTV	.592	
P1	SLAK	26.737	Q1	ARTF	26.737	Q3	ARTF	0.	
S1	ARTF	.331							

SOLUTION # 00005 (INFEASIBLE): PHASE 1 SUM = 27.068									
Q2 SURP WAS INTRODUCED AND Q3 ARTF WAS REMOVED, RESULTING IN									
VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	VARIABLE TYPE		VALUE	
M	ACTV	0.	X	ACTV	0.075	Z	ACTV	.592	
P1	SLAK	26.737	Q2	SURP	0.	Q1	ARTF	26.737	
S1	ARTF	.331							

SOLUTION # 00006 (INFEASIBLE): PHASE 1 SUM = 5.018
 Q3 SURP WAS INTRODUCED AND S1 ARTF WAS REMOVED, RESULTING IN

VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE
M	ACTV	1.629	X	ACTV	0.041	Z	ACTV	.958
P1	SLAK	8.277	Q2	SURP	3.258	Q3	SURP	3.258
Q1	ARTF	5.018						

SOLUTION # 00007 (INFEASIBLE): PHASE 1 SUM = 3.860
 P3 SLAK WAS INTRODUCED AND X ACTV WAS REMOVED, RESULTING IN

VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE
M	ACTV	1.740	Z	ACTV	1.000	P1	SLAK	7.340
Q2	SURP	3.480	P3	SLAK	1.540	Q3	SURP	1.940
Q1	ARTF	3.860						

SOLUTION # 00008 (OPTIMAL): MISFIT = 5.600
 P2 SLAK WAS INTRODUCED AND Q1 ARTF WAS REMOVED, RESULTING IN

VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE	VARIABLE	TYPE	VALUE
M	ACTV	5.000	Z	ACTV	1.000	P1	SLAK	11.200
P2	SLAK	3.860	Q2	SURP	7.340	P3	SLAK	5.400
Q3	SURP	5.800						

THE OPTIMAL SOLUTION IS UNIQUE.

WHEN THE VALUES OF THE VARIABLES ARE SUBSTITUTED IN THE ORIGINAL
 CONSTRAINTS, THE MAXIMUM VIOLATION OF ANY CONSTRAINT IS
 ABSOLUTE ERROR: 1.421E-14 FOR CONSTRAINT Q1
 PERCENT ERROR: 1.000E-13 FOR CONSTRAINT S1

Table A7

PETROGRAPHIC ANALYSIS

	Reactive Components %				Inert Components %				Petrographic Indices and Coke Indices					
	Vitrinite	S. Fusinite	Exinite	Total	S. Fusinite	Micrinite	Fusinite	Mineral Matters	Total	Random Ro	Max. Ro	Balance Index	Strength Index	Stability Index
<u>Western Canadian</u>														
WC6 (raw)	74.5	4.2	0.0	80.8	8.5	1.6	4.5	4.6	19.2		1.2	0.85	4.64	61.60
WC5 (raw)	40.6	12.5	0.0	53.1	25.3	5.5	11.1	5.0	46.9	1.08		1.97	3.90	40.50
WC4 (clean) (sample 1)	68.0	4.5	0.9	73.4	9.1	10.5	4.1	2.9	26.6	1.05		1.02	4.11	56.40
Sample 2	67.3	5.3	0.5	73.1	10.6	7.8	4.8	3.7	26.9	1.05	1.08	1.06	4.15	56.60
Average	67.65	4.90	0.70	73.25	9.85	9.15	4.45	3.30	26.75			0.98	3.92	53.90
<u>Appalachian</u>														
AC3 (raw)	57.0	1.9	3.6	63.1	3.9	10.0	4.2	18.8	36.9	1.05		1.46	3.80	46.30
AC3 (clean)	72.4	2.7	3.9	79.0	5.3	9.8	3.0	2.9	21.0	1.03		0.65	3.76	49.50
AC4 (raw)	40.9	4.7	5.7	51.3	9.4	20.9	7.9	10.5	48.7	1.07	1.05	0.66	3.66	51.20
											1.12	2.45	3.50	26.10
												2.58	3.80	31.40

Table C1
Ruhr Dilatometry Measurements

WC5 - Sink 1.6 x 1.42

At 4300 psi

MESH	[-8x35]						[-35x60]						[-60x100]								
	3°C/min			4.5° C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min					
T																					
T ₁	421	-		477	451	(479)	423	406	(414.5)	468	471	(470)	437	457	(447)	434	504	(469)	468	471	(469.5)
T ₂	471	-		459	471	(465)	438	522	(480)	-	-	-	471	522	(496.5)	507	504	(505.5)	-	-	-
T ₃	507	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c	3.125	0	(1.56)	4.69	3.13	(3.92)	3.25	9.38	(6.31)	0	0	(0)	5.50	3.42	(4.46)	12.7	1.7	(7.2)	0	0	(0)
d	-3.125	1.587	(-0.77)	-4.69	-3.13	(-3.92)	-3.25	-9.38	(-6.31)	0	0	(0)	-5.50	-3.42	(-4.46)	-12.7	-1.7	(-7.2)	0	0	(0)
(c+d)	0	1.587	0.79	4.69	3.13	(3.92)	3.25	9.38	(6.31)	0	0	(0)	0	0	0	0	0	0	0	0	(0)
G Factor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table C1 cont'd
Ruhr Dilatometry Measurements

WC5 - Sink 1.42 x 1.32

MESH	[-8x35]						[-35x60]						[-60]						[-60x100]					
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
T	427	430	422	434	428	444	444	421	444	421	444	421	430	416	423	433	424	428.5	429	436	432.5	459	451	455
T ₁	427	430	422	434	428	444	444	421	444	421	444	421	430	416	423	433	424	428.5	429	436	432.5	459	451	455
T ₂	459	451	466	462	464	533	533	474	503	503	503	503	-	453	-	465	457	461	454	463.5	459	459	451	455
T ₃	-	-	-	-	-	-	-	-	-	-	-	-	542	475	50.85	474	469	471.5	501	488.5	495	459	451	455
c	6.4	6.35	6.37	6.33	7.94	13.31	13.31	8.33	10.81	14.29	11.45	12.31	11.11	22.03	11.02	5.08	10.0	7.54	2.5	14.3	8.35	459	451	455
d	-6.4	-6.35	-6.37	-6.33	-7.94	-13.31	-13.31	-8.33	-10.81	-14.29	-11.45	-12.31	-11.1	3.48	2.59	-5.05	-10.0	-7.54	1.6	-14.3	-6.35	459	451	455
(c+d)	0	0	0	0	0	0	0	0	0	0	0	0	0	3.48	23.72	0	0	0	4.1	0	2.0	459	451	455
G Factor	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1302	0.9463	0	0	0	0.9833	0	0.66	459	451	455

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table C1 cont'd
Ruhrl Dilatometry Measurements

MC5 - Sink 1.32 x 1.22

MESH	[-8x35]						[-35x60]						[-60]						[-60x100]					
	3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min		
	T	T ₁	T ₂	T ₃	c	d	(c+d)	G Factor																
	408	424	(416)	394	414	(404)	412	415	(413.5)	405	-	407				408	414	(411)	417	434	(42.55)			
	433	436	(434.5)	437	437	(437)	447	444	(445.5)	444	-	440				430	433	(431.5)	434	446	(440)			
	472	518	(495)	487	507	(497)	477	486	(481.5)	477	481	(479)	476	511	(493.5)	469	505	(487)	477	489	(483)			
	5.0	0	(2.5)	7.69	1.54	(4.62)	3.51	21.67	(12.59)	13.79	0	(6.9)	22.41	0	(11.21)	11.9	11.9	(11.9)	10.2	3.4	(6.8)			
	65.0	90.0	(57.5)	69.23	84.02	(76.42)	43.86	40.0	(41.93)	62.07	65.57	(63.82)	43.10	26.67	(34.89)	52.5	59.3	(55.9)	76.3	84.5	(80.4)			
	70.0	90.0	(60.0)	76.92	86.16	(81.54)	47.37	61.67	(54.52)	75.86	65.57	(70.72)	65.51	26.67	(46.1)	64.4	71.2	(67.8)	86.5	87.9	(87.2)			
	1.0665	1.1108	(1.0664)	1.0922	1.1079	(1.1007)	1.0664	1.0240	(1.0426)	1.0548			1.0253			1.0459	1.0706	(1.0581)	1.0541	1.0592	(1.0564)			

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table Q1 cont'd
Ruhrl Dilatometry Measurements

MC5 - Float 122

MESM	[-8x35]				[-35x60]				[-60]				[-60x100]							
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min					
T																				
T ₁	414	402	403	427	(415)	417 400	442 405	(429.5) (402.5)	408	385	(39.65)	415	418	(416.5)	411	430	(420.5)	425	425	(425)
T ₂	440	437	(438.5)	437	(439)	451 441	548 445	(499.5) (443)	446	444	(445)	445	445	(445)	425	439	(432)	445	445	(445)
T ₃	544	541	(542.5)	504	(517.5)	549	544	(546.5)	517	510	(513.5)	550	526	(538)	469	488	(478.5)	479	517	(498)
c	7.27	10.71	(8.98)	8.33	(6.94)	9.80 16.39	1.79 16.39	(5.79) (16.39)	11.86	11.48	(11.67)	22.0	18.97	(20.48)	11.3	0	(5.65)	5.4	5.2	(5.3)
d	47.27	44.69	(45.96)	51.67	(61.02)	9.80 24.59	1.79 24.59	(5.79) (24.59)	16.95	16.39	(16.67)	30.0	25.86	(27.93)	27.4	29.0	(28.2)	44.6	46.6	(45.6)
(c+d)	54.54	55.35	(54.96)	60.0	(67.96)	9.80 40.98	1.79 40.98	(5.79) (40.98)	28.81	27.87	(28.34)	52.0	44.83	(48.41)	38.7	29.0	(33.86)	50.0	51.8	(50.9)
G	1.1105	1.0993	(1.1052)	1.0875	(1.1021)	1.0324	1.0302	(1.0313)	1.0213	1.0252	(1.0232)	1.0220	1.0179	(1.0200)	1.0282	1.0674	(1.0449)	1.0491	1.0847	(1.0668)

All test except [-60x100] used [-60] samples and compression at 4300 psi

() = mean

Table C2
Ruhr Dilatometry Measurements
AC4 - Sink 1.6 x 1.42

MES#	[-8x35]						[-35x60]						[-60]						[-60x100]					
	3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min			3°C/min			4.5°C/min		
	T	T ₁	T ₂	T ₃	c	d	(c+d)	G	Factor															
	405	400	(402.5)	400	427	(413.5)	436	436	(436)	424	420	(422)	393	399	(396)	418	430	(424)	438	430	(434)			
	420	428	(424)	435	447	(441)	453	464	(459)	452	460	(456)	434	436	(435)	447	462	(454.5)	442	446	(444)			
	544	485	(515)	486	497	(492)	-	-	-	-	-	-	462	555	(499)	-	-	-	462	474	(468)			
	3.10	4.69	(3.89)	9.71	6.50	(8.11)	8.33	11.57	(9.95)	10.08	11.57	(10.83)	10.34	6.69	(8.52)	5.45	3.78	(4.61)	0	4.92	(2.46)			
	1.55	3.13	(2.34)	4.85	4.88	(4.87)	-8.33	-11.57	(-9.95)	-10.08	-11.57	(-10.83)	5.17	5.02	(5.09)	-5.45	-3.78	(-4.61)	5.17	-4.92	(2.59)			
	4.65	7.82	(6.23)	14.56	11.38	(12.98)	0	0	0	0	0	0	15.51	11.71	(13.61)	0	0	0	0	0	(5.05)			
	0.9534	0.9810	(0.9704)	0.9668	0.9893	(0.9788)							0.9738	0.9797	(0.9718)				1.0274	0				

All text except [-60x100] used [-60x100] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruhri DiTetrometry Measurements

AC4 - Sink 1.42 x 1.32

ME34	[-8x35]				[-35x60]				[-60]				[-60x100]			
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
T	386	386 (376)	386	386 (386)	391	407 (399)	387	391 (388)	386	391 (388)	387	391 (388)	397	414 (405.5)	406	414 (410)
T ₁	422	422 (422)	423	423 (423)	425	434 (430)	429	433 (431)	423	423 (423)	425	430 (427.5)	425	430 (427.5)	430	434 (432)
T ₂	469	474 (472)	522	479 (501)	531	465 (498)	507	507 (507)	511	522 (517)	539	495 (517.5)	539	495 (517.5)	465	473 (469)
c	7.69	12.17 (9.93)	9.50	9.52 (9.41)	14.75	15.25 (15.0)	17.54	16.39 (16.97)	23.14	22.05 (22.59)	15.87	13.11 (14.49)	14.75	14.75 (14.49)	14.75	16.70 (16.70)
d	64.62	80.0 (72.30)	8.06	104.8 (92.7)	36.07	37.29 (36.68)	57.89	60.66 (59.28)	76.03	89.76 (92.90)	30.16	36.07 (33.11)	44.26	44.26 (33.11)	54.24	49.25 (49.25)
(c+d)	72.31	92.17 (82.23)	89.9	114.32 (102.11)	50.82	52.54 (51.68)	75.43	77.05 (76.25)	97.17	111.81 (105.49)	46.03	49.18 (47.6)	59.01	59.01 (47.6)	72.88	65.95 (65.95)
G	1.0828	1.1015 (1.0939)	1.1348	1.0994 (1.1183)	1.0680	1.0287 (1.0406)	1.0774	1.0802 (1.0788)	1.0803	1.0952 (1.0879)	1.0494	1.0439 (1.0498)	1.0551	1.0551 (1.0498)	1.0551	1.0551 (1.0498)

All text except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruh. D1/Tatometry Measurements

AC4 - Sink 1.32 x 1.22

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]			
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		4.5°C/min	
T																
T ₁	404	378 (391)	369	411 (390)	379	-	391	-	367	381 (374)	366	392 (389)	366	392 (389)	381	(390)
T ₂	413	407 (410)	408	415 (411.5)	415	-	410	-	415	421 (418)	406	414 (410)	406	414 (410)	415	(413)
T ₃	506	478 (492)	484	481 (482.5)	471	515	498	524 (511)	547	534 (540.5)	480	477 (478.5)	480	477 (478.5)	488	(482)
c	3.23	12.7 (7.96)	7.94	1.59 (4.76)	13.56	0	(6.78)	3.39	18.64	16.95 (17.8)	20.34	23.21 (21.78)	20.34	23.21 (21.78)	23.21	(12.46)
d	240.32	257.14 (248.73)	257.14	288.88 (273.01)	198.31	155.17	(176.74)	140.68	15.598	201.68 (178.81)	205.08	232.14 (218.61)	205.08	232.14 (218.61)	232.14	(257.88)
(c+d)	243.55	269.88 (256.69)	265.08	290.48 (277.77)	211.87	155.17	(183.44)	144.07	174.57	218.64 (195.61)	225.42	255.35 (240.39)	225.42	255.35 (240.39)	240.67	(270.33)
G Factor	1.1225	1.1108 (1.1202)	1.1461	1.0881 (1.1141)	1.1042			1.1296	1.1833	1.1645 (1.1752)	1.0976	1.0878 (1.0923)	1.0976	1.0878 (1.0923)	1.1045	(1.1059)

All test except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C2 cont'd
Ruhr Dilatometry Measurements

AC4 - Float 1.22

MESH	[-8x35]				[-35x60]				[-60]				[-60x100]								
	3°C/min		4.5°C/min		3°C/min		4.5°C/min		3°C/min		3°C/min		4.5°C/min								
T																					
T ₁	376	-	370	388	(375.5)	365	-	380	377	(378.5)	370	370	(370)	372	-	381	400	(380.5)			
T ₂	400	-	410	412	(411)	409	-	416	416	(416)	416	410	(413)	407	-	418	424	(421)			
T ₃	474	520	(497)	483	(483)	469	469	(469)	498	(492)	487	501	(494)	472	472	(472)	481	489	(485)		
c	4.76	0	(2.38)	16.13	6.45	(11.29)	18.97	0	(9.48)	11.86	18.64	(15.25)	16.95	13.33	(15.14)	22.95	0	(11.48)	25.0	11.29	(18.15)
d	219.05	254.04	(236.94)	251.67	283.87	(267.74)	191.38	200.0	(195.69)	223.73	261.02	(242.37)	213.56	195.0	(204.28)	157.38	175.41	(166.39)	193.33	212.9	(203.12)
(c+d)	223.81	254.04	(239.32)	267.74	290.32	(279.03)	210.35	200.0	(205.17)	235.59	279.66	(257.62)	230.51	208.33	(219.42)	180.33	175.41	(177.87)	218.33	224.19	(221.27)
G																					
Factor	1.1241		1.1319	1.1272	(1.1301)	1.1138				1.1375	1.1229	(1.1299)	1.1318	1.1500	(1.1412)	1.0969			1.0982	1.0999	(1.0992)

All test except [-60x100] used [-60] samples and compression at 4300 psi.
() = mean

Table C4
Proximate Analysis of Sink-Float Sample

Coal Fraction	Mesh of Original Shape	ANALYSIS db%		
		Moisture	Ash	Fixed Carbon
WC5 (R/C)	[-60]	0.33	8.44	23.20
WC5 (R/C)	[-8x35]	0.30	8.38	ND
WC5 1.6 Sink	[-60]	0.51	12.8	23.3
WC5 1.6 Sink	[-35x60]	0.39	32.9	18.5
WC5 1.6 Sink	[-8x35]	0.27	35.4	18.1
WC5 1.6x1.42 Sink	[-60]	0.43	36.5	16.8
WC5 1.42x1.32 Sink	[-60]	0.41	8.20	22.4
WC5 1.32x1.22 Sink	[-60]	0.19	4.44	24.0
WC5 1.22 Float	[-60]	0.19	3.71	23.4
AC4 (R/C)	[-60]	0.31	18.0	23.4
AC4 (R/C)	[-8x35]	0.23	15.5	ND
AC4 Sink 1.6	[-60]	0.23	22.8	21.7
AC4 Sink 1.6	[-8x35]	0.30	66.4	12.2
AC4 Sink 1.6	[-35x60]	0.22	39.4	18.6
AC4 1.6x1.42 Sink	[-60]	0.40	40.7	19.3
AC4 1.42x1.32 Sink	[-60]	0.32	43.1	22.6
AC4 1.32x1.22 Sink	[-60]	0.38	9.60	25.8
AC4 1.22 Float	[-60]	0.33	8.53	25.1

Table C6
Maceral Analysis of Sink-Float Sample

COAL: AC4 [-8x35] mesh

sp.gr.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float	[-8x35] out of [-8] R/C
Ash %db	40.56	42.98	9.57	8.50	15.48
S %db	1.68	0.97	0.82	0.90	0.98
M.M. Coeff.	0.72	0.71	0.94	0.95	0.91
Vit.	26.3	32.7	56.8	58.0	59.5
Exin.	5.6	6.5	2.7	5.8	2.9
S.F.	27.2	16.6	12.3	12.5	11.9
F.	5.0	3.8	2.7	3.4	2.8
Mic.	8.3	11.2	19.9	15.4	13.8
M.M.	27.6	29.2	5.6	4.9	9.0
Random Ro	1.05	1.05	1.05	1.06	1.06
Maximum Ro	1.11	1.11	1.11	1.12	1.12

COAL: WC5 [-8x35] mesh

Ash %db	36.32	8.17	4.43	3.70	8.35
S %db	0.51	0.50	1.07	0.20	0.75
M.M. Coeff.	0.76	0.95	0.97	0.98	0.95
Vit.	20.2	42.9	69.5	79.3	63.6
Exin.	-	1.9	2	-	-
S.F.	44.9	39.9	22.1	12.8	21.9
F.	9.6	6.1	8	1.8	4.0
Mic.	1.8	4.6	4.5	4.1	5.7
M.M.	23.5	4.6	2.9	2.0	4.8
Random Ro	1.06	1.05	1.05	1.06	1.08
Maximum Ro	1.12	1.11	1.11	1.12	1.14

Table C6
Maceral Analysis of Float-Sink Sample

COAL: AC4 [-35x60] mesh

sp.gr.	1.6 x 1.42 sink	1.42 x 1.32 sink	1.32 x 1.22 sink	1.22 float
Ash	37.04	30.38	7.77	5.40
S	1.68	0.97	0.82	0.89
M.M. Coeff.	0.75	0.81	0.96	0.97
Vit.	35.1	40.3	59.5	62.3
Exin.	2.0	3.6	2.8	1.6
S.F.	27.1	20.4	20.0	13.8
F.	5.1	5.7	4.2	7.2
Mic.	5.7	11.0	9.4	12.2
M.M.	25.0	19.0	4.1	2.9
Random Ro	1.05	1.05	1.05	1.06
Maximum Ro	1.11	1.11	1.11	1.11

COAL: MC5 [-35x60] mesh

Ash	24.42	13.55	4.15	7.89	12.01
S	0.51	0.50	1.07	0.21	0.21
M.M. Coeff.	0.85	0.922	0.975	0.956	0.93
Vit.	34.0	44.0	56.9	64.8	50.0
Exin.	0	7	1.6	4	4
S.F.	37.9	35.7	22.8	19.7	29.1
F.	10.2	4.6	10.7	4.8	12.0
Mic.	2.9	7.0	5.5	5.9	1.8
M.M.	15.0	8.0	2.5	4.4	6.7
Random Ro	1.06	1.05	1.05	1.06	
Maximum Ro	1.12	1.11	1.11	1.12	

Table C7
Microfithotype Analysis of Float Sink Fractions

COAL: WC5 [-8x35]							
	1.6 x 1.4 sq	1.42 x 1.32 sq	1.32 x 1.22 sq	1.22 sq	R/C	R/C [-8x35]	
Liptite	-	-	-	-	-	-	-
Clarite	-	1	-	-	1	-	-
Vitrite	8	22	43	80	20	35	35
Vitrinite	32	39	41	17	51	29	29
Inertite	58	27	12	2	21	28	28
SF	(-)	(10)	(7)	(2)	(9)	(11)	(11)
F	(-)	(2)	(1)	(2)	(8)	(4)	(4)
M	(-)	(3)	(-)	(-)	(2)	(2)	(2)
Trimacerite	2	11	4	1	7	8	8
Durite	-	-	-	-	-	-	-
Total	100	100	100	100	100	100	100

COAL: AC4 [-8x35]							
	1.6 x 1.4 sq	1.42 x 1.32 sq	1.32 x 1.22 sq	1.22 sq	R/C	R/C [-8x35]	
Liptite	-	-	-	-	-	-	-
Clarite	1	2	2	1	3	2	2
Vitrite	27	34	38	72	24	32	32
Vitrinite	33	34	43	10	30	24	24
Inertite	32	27	14	15	20	30	30
SF	(3)	(3)	(4)	(5)	(3)	(12)	(12)
F	(2)	(1)	(-)	(1)	(6)	(6)	(6)
M	(3)	(3)	(4)	(1)	(4)	(5)	(5)
Trimacerite	5	3	3	2	16	11	11
Durite	2	-	-	-	7	1	1
Total	100	100	100	100	100	100	100

Table C9
Surface Area Measurements - m^2/g

SAMPLE	MC5					AC 4				
	Raw Coal	Sink 1.42x1.6	Sink 1.32x1.42	Sink 1.22x1.32	Float 1.22	Raw Coal	Sink 1.42x6	Sink 1.32x1.42	Sink 1.22x1.32	Float 1.22
[-8x35]	0.504	0.256	1.621	9.198	0.012	0.051	1.643	0.074	0.047	0.047
[-35x60]	0.597	0.382	0.842	0.892	0.190	0.005	0.833	0.088	0.117	0.102
[-60]	1.248	0.989	1.608	0.670	0.390	0.321	0.289	0.075	0.583	0.790
[-8]	0.133	-	-	-	-	0.067	-	-	-	-
[-35]	0.617	-	-	-	-	0.670	-	-	-	-

(by N_2 adsorption of Ltg. N_2 temperature)